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The future of the Norwegian offshore wind-power industry;

A choice between production of energy or production of technology and competence?

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Abstract

Offshore wind-parks have been in operation since the 1990s. Recent estimates for Norwegian offshore wind-power suggest a potential of up to 14 000 TWh. Yet, only one wind turbine has actually been placed in Norwegian waters; a floating demonstration turbine. This development is in stark contrast to the emphasis on offshore wind-power in some of the neighbouring countries. Thus, it is safe to assume that some of the basic premises for the development of offshore wind-power are not met in Norway.

Inspired by the theoretical framework of Functions of Technology-specific Innovation Systems approach, this study aims to identify key political issues that need to be addressed in order to develop a successful Norwegian offshore wind-power innovation system.

The findings indicate a high degree of *technology push*, combined with a lack of *demand pull*. A lack of coordinated planning on an aggregate level, taking industrial as well energy concerns into consideration, is clear. Furthermore, there is a need to develop the possibilities both for energy-supply as well as for technology- and competence-supply, since these development paths reinforce each other. However, in particular due to growing markets, the prospects of becoming a major technology- and competence-supplier appear most promising.

Key words: Norway, offshore wind-power, energy-supply, technology- and competence-supply, technology-specific innovation system, functions

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Abbreviations

ACER	The European Agency for the Cooperation of Energy Regulators
CEDREN	Centre for Environmental Design of Renewable Energy
CEER	The Council of European Energy Regulators
CMR	Christian Michelsen Research AS
EEA	The European Economic Area
EL	Electricity Act
ENTSO-E	European Network of Transmission System Operators for Electricity
ERGEG	the European Regulator's Group for Electricity and Gas
ES	Energy-supplier
EU	The European Union
EWEA	The European Wind Energy Association
FP7	EU's Seventh Framework Programme
GW	Gigawatt
IEA	International Energy Agency
IFE	Institute for Energy Technology
kWh	Kilowatt hour
MARINTEK	Norwegian Marine Technology Research Institute
MD	Ministry of the Environment
MPE	Ministry of Petroleum and Energy
MW	Megawatt
NINA	Norwegian Institute for Nature Research
NORCOWE	Norwegian Centre for Offshore Wind Energy
NORWEA	the Norwegian Wind Power Association
NOWITECH	Norwegian Research Centre for Offshore Wind Technology
NREAP	EU's National Renewable Energy Action Plan
NTNU	Norwegian University of Science and Technology
NVE	The Norwegian Water Resources and Energy Directorate
PBA	Planning and Building Act
RCN	The Research Council of Norway
SFFE	Centre for Renewable Energy
SMEs	Small and medium enterprises
TCS	Technology- and competence-supplier

TEN	Trans-European Networks
TP Wind	EU’s Wind Technology Platform
TSIS	Technology-specific innovation systems
TWh	Terrawatt hour

1. Introduction

Between the necessity of reducing CO_2 emissions and an increasing global energy demand, lies an opportunity for successful development of renewable energy sources. Access to resources largely determines the potential for the various renewables. Recent estimates for Norwegian offshore wind-power suggest a potential of up to 14 000 TWh. Yearly domestic power consumption, by comparison, is approximately 120 TWh. Yet, although the potential is impressive and offshore wind-parks have been in operation since the 1990s, only one turbine has actually been placed in Norwegian waters at this point; the floating Hywind demonstration turbine. This development is in stark contrast to the priority given to offshore wind-parks in some of the neighbouring countries. Thus, it is safe to assume that some of the basic premises for the development of offshore wind-power are not met in Norway.

This paper will discuss political issues connected to the development of offshore wind-power (OWP) in Norway. Externalities, such as international targets to reduce CO_2 emissions, global energy demand and barriers impeding the development, point to the need to influence the speed and direction of technological change. Thus, the development of a technology should be analysed in interaction with the system in which it is embedded (Hekkert et al. 2007). Being partly immature, OWP is characterized by diversity and insecurity and expectations that have yet to be met. By applying the theoretical framework of an evolving technology-specific innovation system (TSIS), I aim to increase the understanding of the formative phase of this technology. Inspired by a *functions approach* to TSIS (Hekkert et al. 2007; Hekkert and Negro 2009; Alphen et al. 2009), I identify current impediments to a successful development of a future Norwegian OWP innovation system. Furthermore, I analyse the possibilities for two different development paths. Firstly; based on accessibility to resources and the knowledge embedded in the offshore industries, there is a prospect of becoming a major energy supplier (ES). Secondly; based on the high knowledge level that has accumulated within the offshore industries, most prominently the petroleum sector, there is a prospect of becoming a significant technology- and competence supplier (TCS).

1.1 Empirical context

Extensive development of hydropower has turned Norway into the world-leading producer of this renewable energy source, and the national electricity consumption is, thus, supplied with around 99 % renewable energy (Ot.prp. nr. 107 (2008-2009)). Power-intensive industry, like the manufacturers of aluminium, paper and pulp, relies on high electricity supply at affordable prices. Thus, the electricity industry is an integrated part of the power-intensive sector. Compared to most of the renewables, hydropower is a flexible energy source. This means that hydropower stations with reservoirs and regulation capacity, can contribute to the balancing of power supply in Northern Europe. Such plants have the possibility of producing more power when the price is high, and save water when price is low.

As a result of large offshore oil discoveries and a major political initiative during the 1970s and 1980s, Norway is Europe's largest petroleum exporting country today. The petroleum industry has contributed in major ways to Norwegian prosperity and welfare, however, has done little to turn focus on the potential connected to investing in renewable energy, arising simultaneously in many countries due to the oil crisis in 1974.

On the other side, development of the offshore petroleum industry yielded a high petroleum competence level. More importantly, co-evolving with the shipping industry, this process also induced the development of an extensive offshore knowledge base, currently embedded in a large number of technology and competence suppliers. This knowledge base had ample room for growth in an innovative business sector, where large-scale companies had the capacity to further develop the knowledge emanating from the technology suppliers. Thus, owing to exploitation of hydropower and petroleum, as well as particular institutions and politics, the 20^{th} century's Norwegian industry has been characterized by large-scale companies (Wicken 2007). This development induced a path-dependent pattern of resource-based innovations (Fagerberg et al. (forthcoming)). Thus, the dynamic activity within resource-based industries has led to steadily increasing competence and knowledge levels, and, thus, spurred industrial and economic growth.

Thus, the knowledge embedded in the incumbents of the energy sector could induce and facilitate the transition from the production of fossil fuels to renewable energy. CO_2 emissions from Norwegian petroleum industry increased from 11,6 million tons in 2006 to 13,8 million tons in 2008, which represents an increase from a 27% to 31 % share of the total national emission (www.siste.no). There are claims that the sector has a moral responsibility in this respect. Furthermore, a transition would release the economy from the insecurity of the currently intractable oil prices and a declining oil production.

In the cases where fossil fuel can be replaced by electricity, wind-power can contribute significantly to the reduction of CO_2 emissions. The imminent need for a reduction, acknowledged by most research communities, and confirmed in official documents such as the Stern review and IEA reports, has induced “the European energy shift”. Built on the 1997 Kyoto Protocol, The EU Climate Package – the so-called 20-20-20-targets – places stringent demands on the member states. The Commission has stated that, as part of the EEA, Norway is committed to implement this directive. Thus, there is an ever present tension between EU’s directives and Norway’s high production of renewable energy.

1.1.1 What are the feasible possibilities?

Although the influence petroleum industry and hydropower has had on Norwegian industry could be said to have impeded the development of other renewables, they both possess the potential and capacity to contribute to the current development of OWP. The development points to two different, however reinforcing paths;

1) Offshore wind-power as an energy-supplier; ES
2) Offshore wind-power as a technology- and competence-supplier; TCS

1) Hydropower, through its regulation capacity, may greatly facilitate the development of OWP into an ES. Although future energy demands in the Northern part of Europe is disputed, and there are considerable unsolved barriers connected to transmission. The issue of creating preconditions for trading electricity across borders is often seen in relation to the Norwegian EU-directive negotiations. Additionally, electrification of oil and gas platforms provides further incentives to becoming an ES. Finally, on a more general level, the presence of a new energy supplier of considerable size could have a positive affect on other lines of business, most notably new power intensive industries.

2) The offshore technologies may turn the OWP-industry into a TCS. By 2020 the EU-associated European Wind Energy Platform expects a total installed OWP capacity of 40 GW – a development that involves investments in the region of NOK 800 billion (Ot.prp. nr. 107 (2008-2009)). Thus, the combination of high competence and expected growth provides a solid foundation.

1.2 Theoretical foundation

As mentioned, to evaluate the future of a Norwegian OWP innovation system, this study will apply the theoretical framework of a TSIS as the main tool. According to Carlsson and Stankiewicz 1991, a TSIS is used to analyse the “network of actors interacting in a technological area under a particular institutional infrastructure and involved in the generation, diffusion and utilisation of technology”. For a successful development of a TSIS, certain key activities need to be fulfilled. Several recent studies have used the functions approach as a conceptual model in order to identify main policy issues. Thus, inspired by Hekkert et al.’s recent publications (2007 and 2009), this study will be framed by their 7 functions; entrepreneurial activities; knowledge development (learning); knowledge diffusion through networks; guidance of search; market formation; resource mobilisation and creation of legitimacy/counteract resistance to change.

1.3 Research questions

Innovation systems do not, at least at this point, form real theories, thus, it should be pointed out that this study cannot give any clear-cut answers to the research questions (RQ), but rather serve as a provider of clues. In order to analyse the development of OWP in Norway, certain empirical RQs need to be formulated. First of all, it is of interest to find answers to the following overall question:

RQ1. Which basic premises are met in order to achieve a successful development of Norwegian OWP?

The basic premises are defined in the theoretical framework as the seven functions and the interaction between them. “A successful development”, on the other hand, is less clear in this context. This obscurity is related to the complexity of the technology, and the fact that it draws on several different technologies. The complexity, in this respect, implies that more than one possible direction for the continued development is conceivable, and that there may be more than one way to measure success. Thus, it is necessary to consider several alternatives:

In which ways can OWP be profitable for Norway?

As discussed, I have identified two main incentives to designate OWP as a prioritized area. Questions need to be asked along both dimensions.

RQ2. Which basic premises are met in order to become an ES?

RQ3. Which basic premises are met in order to become a TCS?

1.4 Thesis outline

The study will commence with an overview of the theoretical foundation, followed by an account of the research design and methods employed. In order to give a comprehensive overview of the historic development of wind-power in Norway, a short description of the development of land-based wind-power will follow, including a historical and a technological account. This chapter forms the starting point for the main empirical chapter, in which the two offshore wind-power trajectories are described, and possibilities and challenges reviewed. Finally, the empirical findings will be analysed in accordance with the theoretical framework, leading up to the conclusions.

2. Analytical framework

This chapter gives an overview of the theoretical framework employed in this study. An innovation systems framework, based on evolutionary economics, provides for a comprisal of all relevant factors for a successful development. Thus, as mentioned introductorily, a functions approach to TSIS constitutes the main theoretical body. To gain a comprehensive understanding of the development of OWP, insights about the activities and the actors in the innovation system, and how they relate to each other, is a prerequisite. An account of the core concepts; innovation, evolutionary economics, variety and selection, innovation system and its different approaches, and finally the TSIS system and its main elements, is followed by a thorough explanation of the seven decisive functions for the successful development of a new technology.

2.1 The concept of innovation; an interactive process

Innovations are characterized by complexity and uncertainty, and are, thus, difficult to measure. These elements of uncertainty indicate a need for coordination – in order to satisfy technological, economic and other types of constraints simultaneously (Kline and Rosenberg 1986). An innovation can be defined in numerous ways; one starting point is to distinguish between an invention and an innovation. Whereas inventing a new product or process is connected to the initial occurrence of the idea, innovating this product or process also implies carrying it out into practice. Thus, an innovation involves the production, diffusion and use of new knowledge. The process of transforming an invention into an innovation normally comprises a variety of knowledge types, skills, capabilities and resources, and linkages between actors, such as suppliers, competitors, research institutes or policy regulators, is a central aspect of the process. The conditions for commercialization do not necessarily coincide with the invention, thus a time lag may occur between the two concepts. Furthermore, it may take more than one invention to turn an invention into an innovation, in other words, complementary inventions are sometimes necessary for a successful innovation. Additionally, more often than not, the development process continues after the initial market introduction. Kline and Rosenberg argue: “The subsequent improvements in an invention after its first introduction may be vastly more important, economically, than the initial availability of the invention in its original form” (Kline and Rosenberg 1986). Thus, one single innovation is often the result obtained through several interrelated innovations and is essentially a collaborative activity. The understanding of the concept of innovation as an interactive process - *the interactive model of innovation*- contradicts the interpretation of innovation as being based on applied research; *the linear model of innovation*. The linear model assumes a certain order in which the different stages of innovation is expected to go through, beginning with science, followed by development and then production and marketing. The linearity is counter-argued by Kline and Rosenberg, firstly, because this course of events only holds occasionally. More often, innovations take place through reviewing and combining existing knowledge than through scientific research. Secondly, the linear model ignores the fact that the innovation process is characterized by considerations, feedbacks and reconsiderations, in other words close reciprocal interactions between the different stages of the development (Fagerberg 2005). This does not preclude the fact that there are gradual and cumulative aspects to the innovation process; knowledge may accumulate over time, implying that future innovations often depend on past innovations (Lundvall 1992). Thus, cumulated knowledge and routines can be enabling and yet constraining. However, the interaction between different stages can contribute to the avoidance of a negative path-dependent pattern (lock-in) and black-boxing of the innovation. Black-boxing indicates that the knowledge gained through the innovation process becomes a "closed truth"; the distinction between the content and the context disappears when the black box has been closed (Latour 1987). Thus, the interactive approach has its centre of attention on the economic and social context, in which the selection of innovations is carried through and certain technological trajectories become dominant.

2.2 Evolutionary economics

The interactive perspective, or way of analysing innovative activities, is based on an evolutionary model of economy, in which the central concern is dynamic change as opposed to a static balance of economy. Thus, this perspective adds the historical dimension to economic theory. Whereas the basic economic model of neoclassicism assumes a state of perfect competition with perfect information and rational actors; resulting in "right" prices and complete resource exploitation, the evolutionary perspective emphasises the "strong uncertainty" connected to economic development and "externalities" disturbing the balance; in the sense of positive side effects (such as R&D and economies of scale) or negative side effects (such as pollution or diminishing returns). Furthermore, evolutionary economics points to the actors' bounded rationality through routines and rules and their heterogeneity, in stead of rational actors maximising their self-interest. The uncertainty, the variety and selection processes (2.2.1) and the connection to externalities point to time- and path-dependency; "At any point in time many new ideas emerge, but only those that are well adapted to the contemporary selection environment are likely to be applied and form the basis for continuing adaption and improvement" (Fagerberg et al. (forthcoming): 3).

The evolutionary economics is largely based upon the influential work of Schumpeter during the first half of the 20th century, in which he attempted to develop an understanding of how innovation, as a social phenomenon, contributed to the shaping of economic development (Fagerberg: 2005). Drawing on Marx, Schumpeter saw technological competition as the driving force behind evolution, and he defined innovation broadly as 'new combinations of existing resources'.

2.2.1 Variety and selection

The concepts of variety and selection contribute to the understanding of technological development. Whereas variety is a result of new products and technological development, selection, on the other hand, reduces this variety. Through a selection process, the relative economic strength of competing technological alternatives is altered, and the market will favour the survival of a particular technology. The selection is influenced or guided by several factors, such as policy targets and feedback from diffusion. This feedback is often based on expectations connected to the technology. The relationship between the two concepts is reciprocal, in the sense that variety drives selection, while selection shapes variety through feedback. These dynamics are connected to the competitive nature of technological development (Metcalfe 1994).

2.3 The concept of innovation system

"Anything that is not chaos" is, according to Boulding, the broadest definition of a system (Boulding 1985). As opposed to a network, where the actors have to actively sustain the network to ensure the continuance of the relations, a system contains steering elements. This is a feature that enables the establishment and strengthening of stable relations, and, thus, contributes to efficiency and path-dependency. A slightly more specific description of a system is a unit constituted by a number of elements and by the interaction between these elements. Thus, in connection to an innovation; the production, diffusion and use of new knowledge is interacted by these elements (actors) and their relationships (Lundvall 1992). Put differently, the success of a new technology is not determined by its technical characteristics alone, but also by the social system that is part of the development and implementation; the wider context which supports and sustains the activities of innovating firms and the generation of technological variety (Metcalfe 1994). The innovation systems approach is now widely used by public organisations as a guideline for science and innovation policy, as well as in academic circles.

A major focal point within the innovation systems approach is learning processes. Producing or combining new knowledge or combining existing knowledge in different and new ways are, thus, activities which are highly acknowledged and regarded as endogenous to technological change. The scope of a broad interpretation comprises all, or most, activities related to the innovation process. This holistic approach allows for the inclusion of actors and activities such as financial institutions; local conditions and local politics; sectoral measures, such as development of transport and communication or public health service; or public procurements. Thus, since different sub-systems are included in the innovation system, an analysis will depend on an adequate selection of these. In other words, determining which sub-system and social institutions should be included, challenges the historical and evolutionary as well as the theoretical knowledge of the analyst, but points, nevertheless, to an interdisciplinary perspective. Furthermore, innovations systems can include both product and process innovations, and recent suggestions even include non-tangible areas, such as service product innovations (Edquist 2005).

Yet, although widely used to analyse innovative activity, there is still room for conceptual improvements to the innovation systems approach, and they may seem to lack a generally accepted definition or clear boundaries. Evidence can be found in Lundvall’s and Nelson’s definitions; they both use the same term and describe national innovation systems through determinants of innovation processes, such as economic, social and political factors. However, they choose to emphasise different determinants, thus, seem to have different opinions on what the most important factors at work are (Edquist 2005). Selecting which determinants should be included in the innovation system is challenging, because leaving factors out can have negative consequences for the outcome of the analysis, not to mention for the actions taken based on the study. This process is also important because various factors are expected to be interdependent of each other and can, thus, reinforce or undermine each other.

Furthermore, there is room for different interpretations of some of the central concepts, clearly presented by the use of the term “institution”. Whereas some researchers, most prominently Nelson and Rosenberg (1993), associate this term with organizations, others, such as Lundvall (1992) interpret "institutions" as "the rules of the game". According to Edquist, innovation systems consist of organisations and institutions. In this context, institutions are understood as social relationships or trust (Edquist 1997). Thus, institutions can take the form of laws, norms and routines; all factors that may constitute incentives or obstacles to innovation; an interpretation that will form the basis of this study as well. Furthermore, the need for turning the innovation systems approach into a more formal theory, or not, is being discussed by several scholars. A balance between keeping the system somewhat open and not too rigorous, and achieving a more theoretical status has, thus, not yet been reached. The international community is divided on the issue of formalizing the approach (Edquist 2005).

2.3.1 Different approaches to the theory of innovation systems

As an analytical framework, the innovation system can have several different units; national (Freeman 1987; Lundvall 1992, Nelson 1993), regional (Asheim and Gertler 2005) and sectoral (Malerba 2005). An innovation system can also be defined technologically (Carlsson and Stankiewicz 1991, Carlsson et al. 2002). These various approaches to the study of innovations do not exclude each other, but, being based on the same basic understanding of evolutionary economics, they can be said to coexist and complement each other (Edquist 2005).

2.4 The concept of technology-specific innovation system (TSIS)

For studies on socio-technical change, and even more specifically; on emerging renewable energy technologies, the concept of TSIS has been developed. According to Carlsson and Stankiewicz 1991, a TSIS is used to analyse the "network of actors interacting in a technological area under a particular institutional infrastructure and involved in the generation, diffusion and utilisation of technology". The TSIS grows in a co-evolutionary process with the maturation of the technology. Along with the maturation comes an increased knowledge base and growing networks, while one can expect the technology to advance and mature as a result of a growing TSIS, thus they mutually reinforce or impair each other (Hekkert 2009).

2.4.1 Actors, institutions and their relationships (networks)

Three main elements constitute the TSIS: actors, institutions and networks. The *actors*, or organizations, as some scholars prefer, are the operating parts of a system, such as individuals, firms, banks, universities, research institutes and public policy institutes. As mentioned, the content of the concept of institution is widely discussed. However, within the TSIS-framework *institutions* encompass legislative artefacts, such as laws and regulations, policy targets and social norms. The *networks* constitute the relationship between these two elements; the interaction between the actors is regulated by the institutions (van Alphen 2009). No actor is self-contained in its knowledge-creation, thus, policy must therefore be concerned with the learning processes between the actors. The actors enter the innovation system from different cultures, they possess different objectives and they respond to different incentive mechanisms. The heterogeneity implies that the core activity is in fact coordination (Metcalfe 1994).

2.5 The functions approach to a technology-specific innovation system (TSIS)

In connection to the need, expressed by some scholars, for turning the innovation systems approach into a more formal theory, criticism has been raised against the lack of a systems approach. In order to comply with this, and generally as an attempt to further develop the TSIS, emphasis has been turned towards "functioning". "…since one of the characteristics of a 'system' from a general system perspective is that it has a function, i.e. it is performing or achieving something" (Hekkert et al. 2009). Innovation systems are based upon a division of labour in terms of functions and domains (Metcalfe 1994). This division, thus, provides a useful point of departure for the development of a functions approach to innovation systems, a concept first put forward by Jacobsson and Johnson in 2000. For the successful development of an emerging TSIS, certain fundamental activities need to be fulfilled, thus "a technology or product specific innovation system may be described and analysed in terms of its 'functional pattern', i.e. in terms of how these functions are served" (Jacobsson and Johnson 2003). Liu and White (2001) present five activities, which they consider to cover the fundamental activities of an innovation system, whereas Rickne (2001) compiles a list of eleven important functions for a technology-based firm. Thus, in order to identify main political issues that need addressing within a particular technological development, several scholars have, in recent studies, employed some kind of a functions approach. Since different sets of system functions exist, and the classifications of the major functions, contributing to growth and performance, have been revised repeatedly, I have based this thesis on a recent classification; Hekkert and Negro's 7 functions in the *Functions of innovation systems as a framework to* *understand sustainable technological change: Empirical evidence of earlier claims* (2009); function 1: Entrepreneurial activities; function 2: Knowledge development (learning); function 3: Knowledge diffusion through networks; function 4: Guidance of search; function 5: Market formation; function 6: Resource mobilisation and function 7: Creation of legitimacy/ counteract resistance to change.

Function 1; Entrepreneurial activities

Entrepreneurial activities are crucial for a successful innovation system, and new technologies depend on entrepreneurs, particularly in the early stages of the development, in order to overcome uncertain factors. The entrepreneurs' role in the system is to transform into concrete business the potential of knowledge, networks and market. Entrepreneurs can be either new entrants or incumbents seeking to diversify their product line and attempt to take advantage of new technological developments (Kamp 2008).

Within a Schumpeter Mark II sector, such as the Norwegian energy sector, it can, moreover, be useful to practise intrapreneurship to diversify existing firms. Intrapreneurship can be applied to established organizations, perhaps a larger firm, through the deployment of employers with particular entrepreneurial skills. This practice can enable otherwise static organizations to capture the dynamic nature of entrepreneurial management, without the exposure to risks normally associated with entrepreneurial activities.

In addition to the primary function of applying new products or processes in the search for competitive advantages, entrepreneurs can also have a major influence on the development of competence and tacit knowledge (Metcalfe 1994). This kind of knowledge creation is distinct from most of the knowledge created within the realm of universities and institutes, where the knowledge and skills created is mainly codifiable. As the tacit and "sticky" knowledge cumulate, codifying and transferring the knowledge becomes increasingly difficult, thus, further enhancing competitiveness. This firm-based influence on knowledge bridges Function 1 to Function 2.

Function 2; Knowledge development (learning)

Knowledge is a fundamental resource in the modern economy, and a central part of the evolutionary approach is the asymmetric distribution of knowledge and information. It is now widely agreed that knowledge emanates from a great variety of sources; not from science and

R&D alone, but from routine activities in all stages of the value chain. This recognition of learning as a predominantly interactive process also implies increasing interdependence between the various knowledge sources and the fact that neither can be seen in isolation. The interdependence can also be seen in connection to the cumulative and gradual aspect of learning. For a firm, this cumulative process will often lead to a more complex knowledge base, depending on the organizational capability of the firm. Through knowledge spill-over, accumulation can take place at sectoral level as well (Malerba 2005).

Learning processes can broadly be distinguished into four categories; learning-by-using; learning-by-doing; learning-by-searching or R&D; and learning-by-interacting. Learning-by-using occurs through the utilisation of a technology – an activity that may result in new knowledge that could not have been predicted by scientific knowledge. By doing an operation repeatedly, production skills will often improve, thus learning-by-doing may increase the efficiency of a production operation (Kamp 2008; Rosenberg 1982). Thus, innovations emanated from learning-by-doing are most likely to take the form of process-innovations. The process of learning-by-searching takes place at universities, research institutes or in firms with own in-house R&D department. As opposed to the previous two, this process results from a more systematic and organised knowledge search. Another distinction between the two first processes and learning-by-searching can be made, based on a different classification of innovations; according to how radical they are compared to the current technology. This perspective, based on Schumpeter's work, divides broadly between "incremental" or "marginal" innovations (or improvements), "radical" innovations (a new type of machinery, for instance) or "technological revolutions" (involving clusters of innovation with far-reaching impacts) (Fagerberg 2005; Freeman and Soete 1997). Learning-by-using and learning-by-doing will for the most part lead to incremental improvements, whereas learning-by-searching can have larger impact on the development and may lead to "radical" innovations or even "technological revolutions". The fourth learning process - learning-by-interaction - sorts under the next section; Knowledge diffusion through networks.

Within the field of innovation studies, a distinction between tacit and codified knowledge has further contributed to the understanding of learning processes and how they may enhance competitiveness. The concept of tacit knowledge was first introduced in Michael Polanyi's "The Tacit Dimension" in 1964, where he stated "we can know more than we can tell". Tacit knowledge within a company, sector or region is considered to be one of the factors that can contribute to high appropriability. Appropriability denotes to which degree a firm is able to capture the value of its acquired knowledge. Being person- or firm-embodied and dependent on the context, tacit knowledge is difficult to communicate or pronounce to others and is often referred to as “sticky” (Nonaka 1991: 73, Teece 1997: 514). This type of knowledge, for instance brought into the company by employees’ experience, can cumulate. Yet, even valuable and profitable knowledge, accumulated over time, can get depleted, and, as such, no longer serve as an appropriability tool.

Whereas tacit knowledge is “sticky”, codified knowledge can be easily communicated and shared, such as machine manuals or technical information. The more codified knowledge, the less sensitive the process of knowledge exchange is with regard to geography (Bathelt et. al. 2004). Due to aspects of globalization, such as relaxed trade regimes and improved information and communication technologies, ICT, explicit knowledge can, thus, be transferred with gradually less friction. Regions can further improve their competitive edge by fostering interaction between tacit and explicit knowledge. This theory is developed by Ikujiro Nonaka, and the process is referred to as organizational knowledge creation (Lam 2005). Generally, theories about organizational learning are concerned with companies’ abilities to translate individual knowledge into collective knowledge and transforming it into organizational capability. Collective knowledge is thus “…… the accumulated knowledge of the organization stored in its rules, procedures, routines and shared norms which guide the problem-solving activities and patters of interaction among its members” (Lam 2005: 124).

The ability to actively pursuit knowledge from the outside, combined with the ability to distribute this knowledge within the company, can further add to the competitive advantage of a company or even a region or a sector. This ability to recognise the value of external knowledge, combined with the capability to assimilate it and put it to commercial use, has by Wesley M. Cohen and Daniel A. Levinthal been identified as a firm’s “absorptive capability” (Cohen & Levinthal 1990). Building and maintaining network relations with other actors in the market are central activities in order to absorb a high rate of externally acquired knowledge. Relations between actors involve a cooperative element, such as co-developing a strategic component, creating a common standard, lobbying policy makers for a specific technological alternative or sharing R&D expenses. With an increasing level of collaboration and partners to exchange knowledge with, a company can achieve a central position within an industry. This path dependant pattern is associated with a positive market performance (Powell & Grodal 2005).

Thus, concepts like tacit knowledge, cumulated knowledge and absorptive capacity clearly indicates how evolutionary economics are inconsistent with the neo-classical perception that knowledge is a public good, freely available to all. Persistent regional differences confirm this understanding of knowledge as a vital asset.

Although knowledge processes are characterized by diversity, several scholars focus on the fact that firms and sectors still depend on more or less distinct knowledge bases. Asheim and Gertler, among others, distinguish between two main types of knowledge bases, each applying to different industrial settings and each indicating different mixes of tacit and codified knowledge; 'synthetic' and 'analytical' knowledge bases. These knowledge bases, furthermore, involve different codification possibilities and limits, qualifications and skills. The institutions and organizations that are involved may also be different between the two bases of knowledge, as well as the challenges they encounter, for instance facing a globalizing economy. A synthetic knowledge base is characterized by innovations made principally through either application or novel combination of existing knowledge. In industrial sectors where synthetic knowledge prevails, innovation is, thus, more connected to specific problem solving through interaction with other actors in the value chain, and less to R&D. Plant engineering and ship-building can serve as industry examples, and knowledge creation is chiefly in the form of process or product development. Since knowledge often is derived from learning by doing, using or interacting, tacit knowledge seems to have a higher share of the total knowledge embodied within these industries than within analytical knowledge bases – a fact that also imply prevalence of incremental innovations (Asheim & Coenen 2004).

In contrast, an analytical knowledge base prevails in industries where scientific knowledge is of high importance. Within these kinds of industries, innovations are mainly produced through basic or applied research, and companies typically have their own in-house R&D department, and are often connected to universities and research institutes (Asheim and Gertler 2005). Thus, cognitive and rational processes are often the base for creation of knowledge within these sectors, and this implies that a higher share of the knowledge is codified than within the synthetic knowledge base. Another implication is, thus, that radical and disruptive innovations are more frequently to be found here. Asheim and Coenen refer to genetics, biotechnology and ICT as example industries where innovation emanates from an analytical knowledge base (Asheim & Coenen 2004).

Recent studies have identified linkages between the national innovation system of a country and its particular macro-institutional characteristics. In coordinated market economies, such as Germany or Norway, the innovative pattern is primarily drawn from synthetic knowledge bases. Liberal market economies, such as the United States or the United Kingdom, on the other hand, lack the strong systemic elements, and the innovation is more driven by venture capital, entrepreneurs, scientists and market demand. These actors typically derive knowledge from analytical knowledge bases; primarily basic and applied research (Asheim & Gertler 2005).

Function 3; Knowledge diffusion through networks

The process of learning-by-interaction occurs through the transfer or spill-over of knowledge between different actors. Interactive learning through networking can largely influence the development and diffusion of a technology. This activity may involve integration of knowledge acquired in different areas of the innovation system, initially developed outside of the system, with knowledge already existing within (Edquist 2005). This process is particularly important in connection with large and complex innovations, in which no organisation alone is able to acquire all of the knowledge needed for a successful development (Kamp 2008). The settings for knowledge diffusion through networks are varied, ranging from conferences and research collaborations to user-producer relations. There is a close link between function 2 and 3, van Alphen et al. sum up this interaction in the following way; “When the development of knowledge (Function 2) is diffused throughout the network, learning at system level takes place,…” (van Alphen et al. 2009).

Function 4; Guidance of search

Through the development of an innovation, there is often a great variety of technological paths to choose from. Obviously, due to limited resources, not every possible path can be explored, thus, in order to progress, a selection process is necessary, and guidance is required. As previously mentioned, the relationship between variety and selection is reciprocal; variety drives selection, while selection shapes variety through feedback (Metcalfe 1994). van Alphen et al. define the activities of the function “Guidance of search” to the point: “…… the activities within the innovation system that can positively affect the visibility and clarity of specific wants among technology users fall under this system function" (van Alphen 2009). Frequently applied ways of guiding the search of innovation are government policy targets, as well as standards and regulations. Guidance is also often the result of feedback from other actors in the value chain, such as user preferences. Thus, the interaction between the demand and supply side is central to the co-development of market and technology (Metcalfe 1994). Expectations within the research community can also influence the technological development, and thus guide the innovative search. Furthermore, guidance of search can take the form of "technological guideposts" in the sense that certain designs set a pattern for the subsequent technological progress. Once the technological guidepost is established, the following innovation process proceeds through incremental improvements (Kamp 2008; Sahal 1981).

The impact of these selection processes may contribute to increased legitimacy for the technology, as well as stimulate the mobilisation of resources (van Alphen et al. 2009). Furthermore, guidelines, such as long-term policy planning, can give important signals to potential entrepreneurs, and as such, provide incentives for new projects. Hence, there is an obvious connection, and possible interaction, between function 4 and functions 7, 6 and 1.

Function 5; Market formation

The formation of a market is a prerequisite for the diffusion of a new technology. Within an incumbent regime, such as the energy market in Norway, there are considerable challenges connected to the market entry of a new technology. Thus, the formation of protected spaces is decisive for the survival of a new entrant. A whole range of policy instruments, focusing both on the demand and supply side of the value chain, can be deployed in order to facilitate market entry. Such instruments may range from different kinds of subsidies, feed-in tariffs and green certificate schemes to various types of agreements between the government and major actors on the demand side, laws, tax reforms and compensations rules. However, rather than applying a large number of policy instruments, it is of major importance to adequately match the measures with the different stages in the continuous innovation process.

The first stage of technological development; the early innovative phase prior to commercialization is, first and foremost, in the need of R&D. Following the R&D phase, a still immature technology in early deployment requires a different set of policy measures. Market entry in this phase may be most feasible if facilitated through targeted measures such as feed-in tariffs. The feed-in system allows for differentiation, thus the facilitation of a great variety of technologies may be carried out simultaneously. In later phases of the development, when the performance of the technology is more on level with the incumbents, the technology is probably best served by other policy instruments. Niche markets, such as the green certificates markets, are more likely to stimulate the development process towards further commercialisation at this point. The certificate-market exposes the technology to cross-technology competition, and, unlike the feed-in tariffs, gives no handicap-privilege (Midttun 2007).

Function 6; Resource mobilisation

Human as well as financial resources are necessary assets for the development of an innovation. All activities rely on allocation of resources; in fact, all the other functions within this TSIS depend on this one function. Although, type and amount of resources required might greatly vary with time and place, and, like Function 5, the level of maturity will often indicate type and extent.

Function 7; Creation of legitimacy/counteract resistance to change

In order to create an open space within an incumbent regime, the support of advocacy coalitions is required. The diffusion of a new technology can anticipate resistance due to vested ideas, sunk investments and routines. Thus, prior knowledge is one of the factors that may prevent the development of a new technology. Cumulated knowledge can act as a conservative force in the sense that it can bias the decision-making, and, thus, reinforce, resistance to change.

In his early work Schumpeter points to existing knowledge, habits and beliefs as some of the most important challenges for an entrepreneur:

> "knowledge and habit once acquired becomes as firmly rooted in ourselves as a railway embankment in the earth. It does not require to be continually renewed and consciously reproduced, but sinks into the strata of subconsciousness. (….) Everything we think, feel or do often enough becomes automatic" (Fagerberg 2003; Schumpeter 1934)

The creation of legitimacy is, thus, of high importance to Function 1. Function 6, concerning the allocation of resources, also largely depend this function; venture capital is more likely to be invested in projects which appear legitimate. Furthermore, advocacy coalitions and lobbyists can put pressure on and greatly influence the political agenda; if resources are allocated, policy goals are communicated to the public or tax regimes are adjusted in favour the new technology, then legitimacy will increase.

2.5.1 Virtuous and vicious cycles

As shown, the seven functions are interlinked, and the fulfilment of the individual functions is consolidated through interaction. These mutual influences may occur in a circular manner, creating a self-reinforcing virtuous or vicious cycle (Kamp 2008; Jacobsson et al. 2002). A virtuous cycle indicates the successful diffusion of an emerging technology through interaction between the functions. Granting of investment subsidies (F5), for instance, can encourage entrepreneurs to start the work for a licence application for a new project (F1). The TSIS can also develop in a negative direction, through the failure to fulfil a function, leading to reduced activity; a vicious cycle.

3. Research design and methods

This chapter gives an overview of the research design and methods of data collection adopted to answer the RQs. The overview will be followed by a short discussion of the validity and reliability of the study.

3.1 Research design

Yin describes the research design of a thesis as a logical plan which displays how the empirical data will be connected to the initial RQs and ultimately to its conclusions (Yin 2009). The empirical data of this study is linked to the main RQ -*Which basic premises are met in order to achieve a successful development of the Norwegian offshore wind-power technology?* - by the assistance of Hekkert and Negro's 7 functions of TSIS (Hekkert 2009).

3.2 Data sources and collection

Through a combination of reviewing various kinds of literature and conducting interviews, I have analyzed the challenges and possibilities connected to a development of offshore wind-power in Norway.

3.2.1 Reviewing policy-related documents from various sources

Feasibility studies, licence applications, official reports (NOUs), propositions to the Storting (St.prp.), propositions to the Odelsting (Ot.prp.), reports to the Storting (St.meld.) and various EU-web-sites constitute a considerable share of the archive studies. Furthermore, data was collected from the web-sites of many of the central actors, ranging from companies and consortiums to directorates, agencies and interest organisations. Finally, a number of articles from Teknisk Ukeblad, a leading Norwegian engineering journal, contributed in forming an updated impression of the industry.

3.2.2 Interviews

To support my initial findings, I built the study around elite interviews, and conducted interviews with some central actors in the industry. Again, the selection of interviewees was guided by the 7 functions of a TSIS. Unfortunately, interviews with actors engaged within all of the seven main activities were not carried out. However, as interaction between the actors characterizes the development of a technology, the interviewees all contributed to the forming of what can hopefully be considered a complete picture of the process. The interviews were conducted in a semi-structured method, starting off with an initial list of prepared questions, and continued with a dialog influenced by the interviewees and their understanding and insight in the process. An interview guide was prepared, following roughly the seven innovation system functions. However, through the writing process the focus changed; from initially being generally on wind-power in Norway to offshore wind-power in Norway. The interview guide was further developed and changed accordingly.

The following actors were approached and interviewed:

Jørund Buen, Senior Adviser
Point Carbon
Author of *Danish and Norwegian wind industry: The relationship between policy instruments, innovations and diffusion*, Energy Policy 34 (2006)

Nils Martin Espegren, Head of section and presently head of newly appointed Norwegian authority offshore-wind project
Norwegian Water Resources and Energy Directorate (NVE)

Per Finden, Research Manager, Energy Systems
Institute for Energy Technology (IFE)

Øistein Schmidt Galaaen, Philosopher
Øyvind Isachsen, General Secretary
Norwegian Wind Power Association (NORWEA)

Harald Gether, Researcher, Department of Geology and Mineral Resources Engineering and Coordinator of Green Innovation
Norwegian University of Science and Technology (NTNU)

Marius Knagenhjelm, Advisor, Climate, Industry and Technology Department, Research and Technology Section
Norwegian Ministry of Petroleum and Energy

Kjell Olav Skjølsvik, Area Manager New Technology and Renewable Energy
ENOVA SF

John Olav Tande, Centre Director of Norwegian Research Centre for Offshore Wind Technology (NOWITECH)
SINTEF Energy Research

3.3 Validity and reliability

A large amount of sources, with different strengths and weaknesses, are available to scholars researching on the development of OWP. This implies the possibility of applying multiple sources in order to enforce the evidence (Yin 2009). Yet, while the search for reliable empirical sources of evidence is facilitated by this vast amount of information, this does, at the same time, challenge the process. Thus, a fair amount of time has been devoted to the separation between “relevant” and “less relevant” information and this process, too, has been guided by the functions approach of the TSIS. Having made the selection, the analysis is still based on multiple sources – in order to avoid researcher bias as well as to increase the validity of the study. Internal validity refers to how causal relationships are explained, and to what extent the inferences are correct. Validity, in this sense, is secured through explanation building and using logic models. The reliability is ensured by enclosure of references and links to the empirical information in the reference list.

4. Land-based wind-power

Driven by the increasing need for energy, extensive R&D from the 1970s onwards has resulted in a relatively high diffusion of wind-power in several parts of the world, and land-based wind-power is considered one of the mature renewables of today. This chapter is included to set a backdrop for the technological development of OWP. Above water the technologies are largely similar, thus, the knowledge and experience from land-based wind-power can to a large extent be transferred to sea – providing challenges and possibilities of generally harsher conditions, higher wind velocities and more space are taken into account.

4.1 History and current situation

Modern wind-power has its origin in the early 1970s, when the oil crisis invoked an active search for alternative energy sources. Through research and prototypes, many countries began to explore the production potential. In Norway, an extensive R&D programme was carried out during 1979 to 1982. However, production costs and technical challenges were considered too high, thus, the results from this research work were only to a very limited extent followed up (Njølstad 1999). Nevertheless, the improved wind-power technology began to receive more attention in Norway from the mid-1990s onwards. Policy measures to support the industry were initiated just before 2000, and the first long-term target was announced; 3 TWh within 2010. This goal, a period of trading with Dutch green certificates, granting of production subsidies between 1998 and 2004, as well as investment subsidies introduced in 1998, led to a substantial increase in the number of turbines and production capacity. However, during the same period the new Energy Law, EL, was passed. The EL involved privatization and deregulation of the entire power sector, which in turn, led to a power-surplus due to large-scale development of hydropower. The low prices following the power-surplus strengthened the argument that wind-power yielded too little for too high price (Buen 2006).

Up until 2001 the Norwegian Water Resources and Energy Directorate (NVE) was responsible for supporting renewables, which was then taken over by the new state enterprise ENOVA. Yet, despite the establishment of a separate agency, unpredictability has characterized the public policy system for wind-power. Due to the Dutch trading scheme, the investment subsidy was reduced from 25% to 10%, only to be raised back to 25%. The termination of the negotiation with Sweden about green certificates was another major setback for the industry (ENOVA and green certificates are accounted for in chapter 5). A transitional arrangement of 8% production subsidy per kWh was suggested as an alternative, but the resolution was never carried through. By way of comparison, a similar subsidy in Germany varies between 64 and 112 øre per kWh.

The only financial support presently available for Norwegian wind park projects is investment subsidy. While a total of 34 projects have been licensed, only 15 wind parks are in operation in Norway, out of which 11 have received support from ENOVA. In addition, 4 new projects were granted support in July 2009. The entrepreneurial actors within the industry are mainly medium-sized power companies. The continued development of land-based wind-parks is required for at least 3 purposes; in order to the 2010-target of 3 TWh, to secure power-supply to vulnerable parts of the country, such as Central Norway and, finally, to build a wind-power knowledge base as well as to give important signals to offshore entrepreneurs.

Siting difficulties have frequently challenged land-based wind-power diffusion. Two different interpretations of sustainability, with the classical view on one side, arguing for the preservation of natural landscapes, and the promoters of renewable energy on the other side, have developed a relatively deep cleavage in Norway – a cleavage the wind-power industry seems to be suffering from. Whereas the wind-power industry's lack of legitimacy – induced by local resistance and nature preservation - by no means is confined to Norway, the fairly comfortable energy situation may have made resistance based on such conditions more prominent than in many other countries.

4.2 Technology

Air in motion contains (kinetic) energy, and wind-turbines transform parts of this into electric energy. Through the wind's motion, the wings drive a generator inside the machinery house, and the electric power is transferred to the main grid through cables.

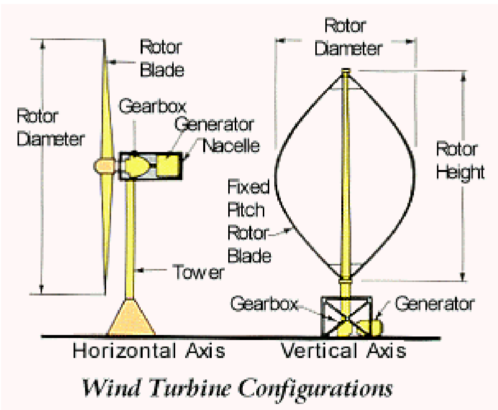

Figure 1 (www.awea.org)

The main components of a wind-turbine system are blades, which convert the energy, nacelle, tower and electronic equipment. The towers are mainly tubular and produced from steel, whereas the blades are made from fiberglass-reinforced polyester or wood-epoxy. Turbine sizes vary, with rotor diameters ranging from approximately 50 to 90 meters, and towers more or less the same size.

5. Offshore wind-power

This chapter will give an account of Norwegian OWP, including a brief description of the technologies and the most striking challenges and possibilities. Generally, the OWP technology is more immature and is characterized by additional challenges compared to land-based wind-power; most prominently issues connected to installation, grid and maintenance, all of which imply higher costs. Thus, the starting point for a successful development of OWP in Norway is characterized by large financial risks and a small home market. While acting as barriers to the development, many of the challenges at the same time represent important industrial opportunities for Norway. Already in the front edge of offshore development, with a high competence level of technologies related to oil and gas, cables and grid and other marine industries, Norway has much to profit from an extensive development of OWP. Thus, not only is the technical potential large, but the industrial potential for the build-up of an entire cluster connected to offshore wind-power is feasible. Besides the prospect of becoming an ES, this industrial potential is at the core of the incentives for OWP.

There are two main technological trajectories within OWP; generation from bottom-fixed installations and from floating installations. As implied in the terms, the division is primarily connected to the fact that their foundations rely on different technologies, and may, thus, come to involve different actors. Whereas bottom-fixed wind turbines have been in operation since the last half of the 1990s, most notably in the United Kingdom and Denmark, floating turbines have only reached the testing stage. Furthermore, the difference in foundation technologies is closely connected to the siting; bottom-fixed installations are placed in shallow waters, whereas floating wind-power is assumed to have a future in deep-sea waters.

The production potential, too, greatly varies between the two trajectories. According to study from 2008, the physical potential for wind-power in shallow waters (in this study defined as depths less than 20 meters) is estimated to be between 6 000 and 30 000 MW. When water depths down to 50 meters are included, the potential is valuated to be between 13 000 and 55 000 MW. The physical potential increases significantly when depths down to 100 meters are taken into consideration, ranging from to 40 000 to 140 000 MW. Except for conserved areas, this study does not take external factors, such as shipping, defence and environmental issues, into consideration. The actual potential is therefore assumed to be lower in both cases (NVE report 9/2008). However, the physical potential alone seems, at this point, considerably higher for water depths where floating wind turbines are expected to be placed, than for water depths suitable for bottom-fixed wind turbines.

Furthermore, should any bottom-fixed wind parks be set to commercial operation in Norwegian waters, they will most likely sort under the law covering electricity production, the Electricity Act (EL 1991). The EL has jurisdiction as far as the baseline, which includes most of the shallow areas. The major part of the future floating wind-power production, however, is likely to be covered by a new, proposed law; havenergilova, to be proposed to the Parliament in 2012 (Ot.prp. nr. 107 (2008-2009)). (Further accounted for under 5.4.2).

5.1 Bottom-fixed offshore wind-power

Most of today's offshore wind-parks are situated inshore; less than 10 kilometres off the shores and in water depths down to 15 meters. As far as the expectations to increased production capacity compared to land-based wind-power, this is to a large extent connected to higher and steadier wind velocities. However, there are also advantages connected to transportation of the elements. It is considered less challenging to transport large blades by ship than by road (www.awea.org). Thus, wind turbines offshore can be assembled with larger blades, which is another factor increasing the amount of energy generated.

Particularly in connection to the elements *above* water, bottom-fixed OWP shares many features with land-based wind-power (chapter 4). Thus, the turbines are considered technologically mature, although some parts are still under testing. The main divergence is the foundation, indicated by the number of patents as well as expenses. The turbines are fixed to the seabed in shallow waters; in water depths down to 30 to 40 meters. Foundations fixed to the seabed as far down as 80 meters are under testing. There are two foundation methods; gravitation and monopiles. A gravitation foundation is normally a concrete case filled with sand, whereas the monopile is a pipe, which – depending on the soil condition - is piled or drilled into the seabed (NVE report 9/2008).

5.2 Floating offshore wind-power

Floating wind-turbines are tethered with cables to the seabed. As to towers, blades and most of the elements on top of the platforms, these share most of the features with other turbines (see chapter 4 for technical information). The technological features from the platforms and down are yet so immature, that it suits the purpose better to describe them under each of the major projects (5.4.1 *Floating offshore wind turbines*). Floating installations are projected for siting in deep waters; from 40 to 400 meters. Undoubtedly the most immature among the wind-power technologies, floating turbines, nevertheless, receive much attention in Norway. This interest is closely connected to the extraordinarily good wind conditions. Wind velocities are higher and steadier further out in the ocean and turbines are, thus, expected to capture more energy. A floating turbine is said to be able to generate four times as much power as a bottom-fixed turbine (www.economist.com). Furthermore, more space makes competition for sites less.

5.3 How would a value chain for energy production look?

On the demand side of the Norwegian energy industry, approximately 30 % is distributed to private households, whereas private and public service industries use around 25 %. The share of the power intensive industry is approximately 30 %, while the remaining 15 % is distributed to other sectors. The end users buy power from the energy suppliers who purchase power through the Nordic power exchange, Nord Pool ASA, or buy directly from the energy producers. However, consumers cannot determine what kind of energy is in the grid, and all energy types are bought in the same market. (www.kraftkartet.no). Thus, price and reliability of supply are the major concerns.

Unsheltered weather conditions and salt water taken into account, above water the turbine parts are basically the same as land-based ones. Thus, blades, gear boxes et cetera, have gone through a selection process since the 1980s. Norwegian suppliers to the land-based wind-power industry do exist, but have been highly export-oriented due to the lack domestic market (Buen 2006).

Based on wind-power production in other waters, and the Norwegian energy situation, figure 2 describes how a potential value chain for energy supply from OWP could look. However, the fact that no offshore turbines produce energy at this point remains. Thus, the figure should be regarded as purely indicative.

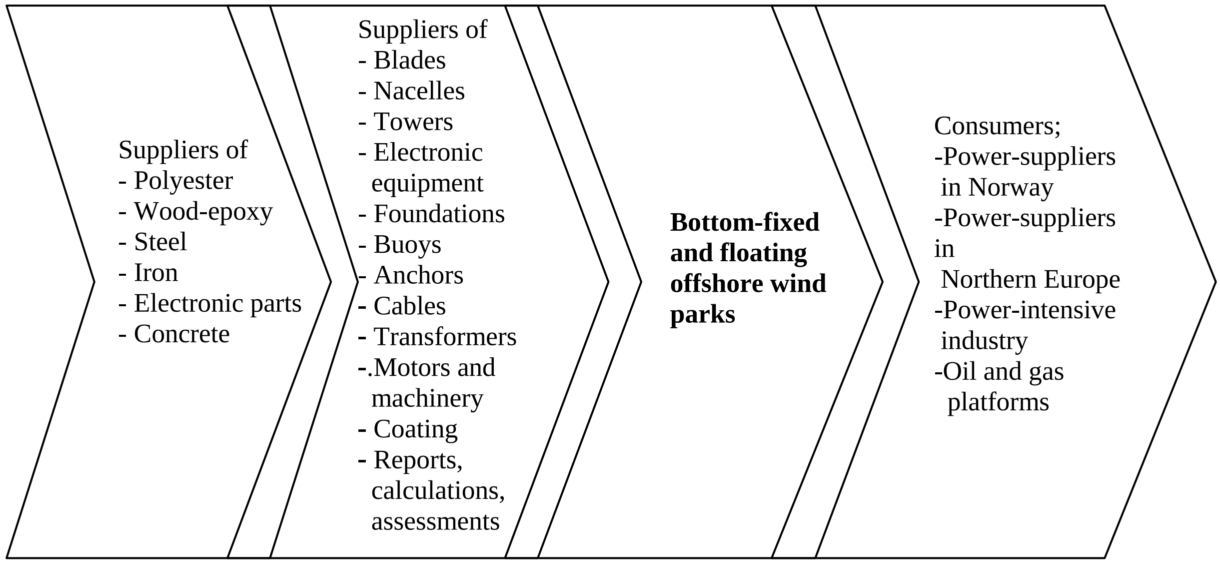

Figure 2

5.4 Actors involved in Norwegian offshore wind-power

5.4.1 Industry and firms

Bottom-fixed offshore wind-parks

No large corporations have so far shown an interest in developing bottom-fixed offshore wind parks in Norwegian waters. However, StatoilHydro and Statkraft are co-owners in a large wind park project in British waters, Sheringham Shoal Offshore Wind Farm, scheduled for 2011. Furthermore, the same two companies take part in a consortium; Forewind, presently bidding in the third British license round for OWP.

The interest for bottom-fixed OWP in Norway is chiefly to be found among medium-sized power companies. Thus, the structure of the industry seems, to a higher extent, to follow along the same path as the land-based wind-power industry. In the waters off the coast of Møre, the company Havgul has had wind park projects licence-handled and appealed. One of the projects, Havsul I, was recently sold to a company owned by 7 power companies; Vestavind Kraft. Havsul I, an offshore wind park project containing 178 bottom-fixed turbines, was as late as September 2009 given licence. All in all, 12 projects along the coastline are under planning.

Floating offshore turbines

The technical immaturity guides the activities of the actors in this segment. Both the research community and the entrepreneurs are engaged in pilot projects. Floating turbines are attracting larger corporations as well as medium-sized companies. Two - three major entrepreneurial projects are under development. The projects have been conceived upon during the current decade, but have reached different testing stages and are developing different floating technologies. Vestavind Kraft, too, is exploring the floating segment of wind-power with its Stadtvind.

Hywind

StatoilHydro, Siemens and Technip are the major stakeholders in the Hywind project, the world’s first full scale floating turbine. In July 2009 the turbine was connected to the grid, and a two-year test period, generating approximately 1 MW, has commenced. This prototype is the first large turbine to be deployed in depths below 30 metres; the ocean depth in the area is 220 metres. However, the turbine is designed to operate in depths down to 700 metres; anywhere in the North Sea.

The tower is placed on a steel buoy, containing 300 tonnes of concrete and extending 100 metres below sea level, tethered by steel cables to the seabed. A computer system controls the direction of the blades.

Picture 1: Hywind

SWAY

Simulations of SWAY have been carried out since 2001, and a full-scale demonstration license was issued in 2009. The ocean depth where the turbine is planned located is approximately 130 meters, and, this tower, too, extends far below the surface. However, the lower end consists of a floating pole and the tower is anchored to the seabed with a single pipe and a suction anchor.

SWAY cooperates with several large industrial actors, including StatoilHydro, Statkraft, Shell Technology Norway and Lyse. The designated location for the testing is in the same area as the Hywind. Additionally, there are plans for a centre for offshore renewable energy on the same location in Karmøy, in which the demonstration turbines can be integrated (Licence application; SWAY).

Picture 2: SWAY

WindSea

In 2011 a collaborative project between Statkraft and two partners is planned to result in a pilot with three turbines per platform. This solution implies larger expenses connected to the platform, but a reduction of costs per MW (Website of WindSea).

Picture 3: Windsea

The offshore-technologies

Following in the wake of the development of OWP, vigorous technology communities concerned with complex subsea constructions and severe weather conditions emanate. The shipping industry participates in the installation phase, through transportation of turbine parts and cables, and in the operation phase, through service and maintenance. In Norway, the shipping industry has a long tradition, and is among the most advanced in the world. To adapt to the petroleum policy requirements, the shipbuilding industry in the late 1960s evolved into a structure of sectional construction, rather than the building of complete units. This transformation increased the specialized expertise (Engen 2009: 181). Thus, owing to a combination of an initially high competence, and the central control characteristic of the

Norwegian petroleum industry, technologies emanating from the shipping industry have a high industrial capacity to undertake complex construction challenges of OWP.

Supply of cables and grid constitutes another important activity within the OWP industry; central Norwegian actors deliver subsea power cables, transmission system and transformer stations. Equally important is the industry involved in the development of foundations, a sector where Norwegian companies already possess a prominent position. All of the above-mentioned groups draw on the extensive knowledge base developed within the petroleum industry.

Norwegian suppliers of traditional wind-power parts, such as turbines, as well as sub-suppliers of parts for turbines, such as iron casting, have been in production almost since the beginning of modern wind-power industry, delivering parts to a global wind-power market (Buen 2006). Furthermore, numerous special products are connected to the evolving offshore industry, such as remote control systems, customized electrical machinery, motors, hydraulics and coating are being developed. Finally, an extensive service industry accustomed to deliver reports and calculations to offshore companies, such as impact assessments, forecasts and climate reports, has a large growth potential in connection to OWP-development.

Both in Central Norway and in Western Norway initiatives have been taken to form “wind clusters”, respectively including the research centres NOWITECH and NORCOWE (section 5.4.3). Moreover, a partly governmental networking organization, INTPOW, offering market information and settings for interaction between domestic and foreign actors within the field, has recently been established.

5.4.2 Government and authorities and their legal framework

The Ministry of Petroleum and Energy (MPE), NVE, ENOVA and The Research Council of Norway (RCN) constitute the principal public actors for the development of OWP. MPE holds the overall administrative responsibility for the coordination and integration of energy policy in Norway. Offshore wind-park projects need approval from MPE under the EL. The EL states the need for license (§3-1), and has jurisdiction as far out as the baseline. However, approval from The Ministry of the Environment (MD) under the Planning and Building Act (PBA) is also required. Besides the legal framework of the EL and the PBA, the pollution law (covering possible turbine-noise), the nature conservation law and laws covering health on municipal level may be brought into a concession process.

The previously mentioned draft law, havenergilova, is part of a national strategy for OWP. Chiefly based on the regulation principles of the petroleum sector, with blocks opened for tender and licensing rounds, the purpose of havenergilova will be to regulate all offshore renewable energy production, outside of the baseline (St.meld. nr. 37 (2008-2009)). The final juridical solution to the area between land and the baseline could be altered, as a result of the hearings of the proposed law.

NVE is MPE's responsible organization for management of wind resources, which includes licensing authority. As part of the process with havenergilova, NVE has been appointed head of a project, consisting of members from four other governmental agencies as well. The purpose of the project, which will submit its findings in 2010, is to map the area outside of the baseline. The mapping will include impact assessments, infrastructure and market, and, thus, seek to identify the most suitable sitings for offshore wind-parks.

ENOVA's responsibility makes it MPE's main instrument in the promotion of renewables. MPE's management of ENOVA is restricted mainly to the establishment of goals and criteria for performance reports (St. prp. 1 (2008-2009)). By means of an earmarked levy on the transmission tariff of 1 øre per kWh, the Energy Fund (Energifondet) constitutes ENOVA's budget. The main policy instruments available to energy agencies can be divided into three; various kinds of feed-in (such as production subsidy), investment subsidies and green certificates. ENOVA currently has the authority only to grant investment subsidies of up to 25%, and projects are ranked according to cost-efficiency. To receive investment subsidy, two formal criteria must be met; firstly, a legally binding license and, secondly, access to sufficient grid capacity should be secured (enova1). As mentioned, the green certificates cooperation with Sweden was resumed in 2008. In September 2009 the negotiations were finally successful, and the system will replace ENOVA's current wind-power programme in 2012. The system will involve the development of 25 TWh new renewable energy, and all Swedish and Norwegian renewables producers will participate. Up until the green certificates become operative, ENOVA will continue its investment subsidy scheme. The principle of green certificates implies the right of renewables producers to sell the green certificates in proportion to the quantity of electricity produced. Electricity consumers are obliged to purchase a certain amount of the certificates – in proportion to the consumption - and are, thus, ensuring demand. The income from the green certificates trade comes in addition to the market price for electricity.

ENOVA, furthermore, supports full-scale demonstration projects with the purpose of testing turbines under genuine, Norwegian conditions. This part of ENOVAS mandate is particularly important to the immature OWP technology, and has made the Hywind project possible. According to havenergilova, the government now prepares for a particular program to handle demonstration projects. The program will be managed by ENOVA, but will have a budget of its own and particular reporting requirements.

While ENOVA handles the support of commercial and test projects, RCN handles the R&D, including support to testing on a smaller scale, for instance 1:4. Support to further research on OWP is distributed through RENERGI – RCN's R&D program for the promotion of renewables. The programme is meant to embrace a great variety of innovative activities, spanning from basic to applied research as well as including social studies.

On a more general level, most of the innovative activity in Norway is handled through the public support actors of Innovation Norway and SIVA, a governmental industrial development corporation. In addition to these major public support actors, the county municipalities and other regional actors influence innovative activities and industrial development. The Foreign Service, furthermore, contributes to possible internationalisation and international knowledge transfer.

5.4.3 Universities and research institutes

Three large research organizations have joined forces through the establishment of Centre for Renewable Energy (SFFE). The co-operation between Norwegian University of Science and Technology (NTNU), SINTEF and Institute for Energy Technology (IFE) was formalised to enhance knowledge about renewable energy. Furthermore, the 2008 climate policy compromise between the government and the majority of the opposition, klimaforliket, resulted in eight new research centres (FME), appointed for a period of eight years (Report No. 34 (2006-2007)). The three with offshore relevance, receiving a total of NOK 45 million in 2009, include NOWITECH, NORCOWE and CEDREN.

Norwegian Research Centre for Offshore Wind Technology (NOWITECH) in Trondheim is run by SINTEF Energy Research, a division under the SINTEF Group, the largest research institute in Scandinavia. The SINTEF Group, among other things, engages in partnerships with industry and public sector and develops new companies. NOWITECH consists of eight "Work Packages", engaged in different aspects of OWP, such as grid connection or operation and maintenance. Thus, a multidisciplinary approach ensures a broad technological focus, and a goal of finding cost-reducing solutions guide the process, yielding an emphasis on material competence. This includes research on maintenance; such as finding good routines for renewing blades, which is linked to the search for robust solutions. Activities within these areas may give feedback to design development and induce the development of maintenance-free concepts, such as remote control systems.

NTNU, IFE and the Norwegian Marine Technology Research Institute (MARINTEK) all participate in these "Work Packages", which aims both at bottom-fixed and floating technologies. In addition to central international actors, most national research and industry actors in the field participate in NOWITECH, and together with RCN contribute as co-funders. Close industrial links are evident in composition of the board as well, where 8 out of 11 members represent the industry.

Christian Michelsen Research AS (CMR) in Bergen is responsible for Norwegian Centre for Offshore Wind Energy (NORCOWE). NORCOWE soon to be put into operation, too, will engage in the development of OWP, with a particular focus on wind and sea modelling. Like NOWITECH, NORCOWE is financially supported by industrial actors, and collaborating partners are Norwegian and Danish universities. The focus of the two FMEs are similar, however the activities are to be coordinated through tight co-operation.

Centre for Environmental Design of Renewable Energy (CEDREN) is established to find solutions to minimise any negative impact on ecology or society which may trigger resistance to renewable projects. This target comprises further research into the interplay between hydropower and wind-power and how wind-power may become a supplement to hydropower. SINTEF Energy Research is also responsible for CEDREN, which additionally co-operates with several partners, most prominently Norwegian Institute for Nature Research (NINA).

Norway participates in several international research co-operations, most prominently the EU's Seventh Framework Programme (FP7), and other EU projects, such as the Strategic Energy Technology Plan (the SET Plan), EU's Wind Technology Platform (TP Wind). Participation in co-operations supported by the International Energy Agency (IEA) is also in progress.

RENERGI will during the autumn of 2009 complete a report called "R&D roadmap for Norwegian offshore wind power". Central concerns are to give an overview of the costs related to current wind-power, to point at the needed cost reductions to make OWP competitive, to make a market analysis of the North Sea area and finally to investigate the need for support in relation to costs and benefits for the society (Ot.prp. nr.107 (2008-2009)).

5.4.4 NGOs, environmental and special interest organisations

The promotion of wind-power is first and foremost performed by NORWEA, the Norwegian Wind Power Association. NORWEA's membership list includes approximately 90 members, ranging from power companies and technology-suppliers to research organizations. Actively fronting the industry, lobbying and serving as a coordinator and intermediator, NORWEA fills an important function for the potential OWP innovation system.

Due to the offshore siting, there is reason to anticipate less controversy over OWP than what has been the case for land-based wind parks. However, factors like shipping lanes, fisheries, military utilities as well as demands to protect particular birds and sea mammals could lead to controversies off the shores as well. Conflicts may arise with other industrial sectors, defence institutions or conservationists, thus, the projects rely on thorough impact assessments.

Turbines sited within view of the coastline may cause conflicts, partly for the same reason as for land-based wind-power. The conflicting interpretations of sustainability that has formed the core of the siting difficulties for land-based turbines have divided the environmental organizations in their view on wind-power. Nevertheless, due to the increasing understanding of the need to reduce CO_2 emissions, a vast majority strongly favour OWP. Whereas Bellona, ZERO and Natur og Ungdom actively promote the development, Naturvernforbundet takes a slightly more sceptical stand, arguing for carefully considered sitings of wind parks.

5.5 The prospect of becoming an energy supplier

In general, there are three main factors that challenge the successful development of OWP into a major energy supplier; the immature technology itself, the targets and the legal framework supporting these targets and last, but not least, market formation.

5.5.1 Technology, knowledge and knowledge diffusion

Research, full-scale and smaller scale testing is vital in order to make OWP competitive. For bottom-fixed turbines, solutions reducing the costs of the foundations are needed, and different depths require different solutions. Maintenance represents another challenge, such as solutions for easier access to the turbines. Measuring methods, particularly for the large, fairly new turbines, is another example.

Knowledge gained through research and testing of bottom-fixed turbines may benefit the floating turbines as well. However, there is obviously a different set of challenges connected to the floating foundations, such as the need to reduce the weight of the tower and the parts assembled there, and thus, testing of materials. Furthermore, while bottom-fixed turbines often have a landing platform on the top for maintenance purposes, floating turbines cannot be built with an integrated platform because they are constantly in motion. Other bottom-fixed turbines in shallow waters are attended to by the use of repair vessels that can jack themselves up on the seabed for stability – a method not suitable for deep waters. Maintenance on floating turbines can, at this point, only be performed from repair vessels and in good and stable weather. Thus, research to improve maintenance procedures is much needed, and remote operation from land is being explored.

5.5.2 Guidance of search; regulations and targets

As explained, the Norwegian wind-power target is the production of 3 TWh within 2010. Awaiting the outcome of the EU-directives negotiations, no target has been set for the period after 2010. Klimaforliket states a target of carbon neutrality by 2030, which involves an increased share of renewables in the energy mix, however does not state how this is to be distributed.

The EU directive

The Climate Package involves a 20% cut in emissions of greenhouse gases (GHG) by 2020, compared with 1990 levels; a 20% increase in the share of renewables in the energy mix; and a 20% cut in energy consumption. Whereas other EU/EEA-members can choose to reduce production from coal-fired or gas power stations in order to reach EU's targets, Norway's major energy source is already renewable. Thus, the energy situation is in relatively stark contrast to that of the Continent. Due to Norway's large hydro-power production and the non-member status, specific terms are being negotiated. To assist the members in fulfilling their climate commitments, a template for a detailed renewables plan has been formulated; National Renewable Energy Action Plan (NREAP). The member-states are obliged to submit the first draft within June 2010 (EU's NREAP form).

A lack of Master Plans?

Not only does uncertainty prevail regarding Norway's obligations to submit the NREAP. An Energy Master Plan, in which renewable energy sources, energy efficiency, fossil fuels and CCS are all accounted for, is a common part of the legal framework in many countries. Partly due to the abundance of natural resources, a similar plan for Norway has not been worked out. The last governmental energy report was delivered in 2004, and the initiative to a new report, taken by the previous Minister of Petroleum and Energy, has been abandoned.

In order to achieve their renewables targets and to secure energy supply, many countries have also established Wind-power Master Plans. Norwegian hydropower projects have been developed based on a Master Plan since 1986. Contrary to hydropower, however, a similar wind-power plan has not been prepared either, thus, wind-power projects rely entirely on the licensing process.

5.5.3 Market

Reducing costs

The uncertainty connected to calculations of costs for OWP-development can be illustrated by the investment costs worked out by the British Department of Trade and Industry and NVE respectively; for depths down to 30 meters the costs vary between NOK 20 – 22 million and 23 – 28 million per MW. Some studies indicate increased expenses for floating turbines due to the foundation technology, whereas another study indicate the possibility of lower costs compared to bottom-fixed turbines.

Although purely indicative, the operationalised table 1 shows how investment and operation costs differ between bottom-fixed and floating turbines. Regardless of the large variety, however, the need to increase competitiveness remains.

Turbine	Investment costs NOK/year - kWh	Operation costs øre/kWh
Bottom-fixed , depths down to 30 meters	2,8 – 4,5	12 – 18
Bottom-fixed, depths between 30 and 60 meters	3,0 – 5,0	12 – 18
Floating	3,2 – 5,5	15 - 20

Table 1 (Ot.prp. nr.107 (2008-2009)).

There are large expenses connected to the pre-commercial phase of OWP projects, in particular to transportation, installation and infrastructure. Once in operation, production costs appear to be more on level with a mature technology. This is clearly indicated by the relatively low production costs of land-based wind-power; ranging between 10 to 12 øre per kWh (www.vindkraft.no). Yet, as mentioned, pending further research, maintenance costs are expected to be higher than for land-based turbines.

Power supply to whom?

An impending situation of power-surplus in Norway is a frequently debated issue. A Norwegian Official Report from 1998 states that different future scenarios all point to growth in the national energy consume towards 2020 (NOU 1998: 11). And, at least up until 2007, Norwegian demand for energy *did* increase with 1 – 1.5 % per year (van Alphen; Trømborg et al., 2007). However, recent reports anticipate low growth in energy demand in all the Nordic countries. The decrease in demand relates to several factors, such as a general shift in electricity habits due to the financial crisis, and the large Finnish nuclear plant, due for operation in 2012 (Nordic Energy Perspectives 2006). Regardless of the debate: a substantial increase in power-production will at some point give a power-surplus in the Nordic region and may yield low electricity prices.

However limited in extent, the prospect of becoming an ES to oil and gas platforms, appears more feasible. Electrification of platforms would mean the possibility for wind-parks to produce energy for consumers in geographic proximity. For the petroleum industry, power-supply from nearby wind-turbines would both contribute to the reduction of electricity costs compared to current fossil-fuel solutions, as well as reduce CO2-emissions. This prospect should, however, be seen in connection to peak oil; a decreasing petroleum production and, thus, limited future prospects.

All in all, the energy situation in Norway does not appear to provide much home market for new renewable energy. So, if the goal is to become an ES, the market is to be found abroad, where the energy demand is more evident. The kind of balancing trade that can be attained from a wind- and hydro-partnership, in which hydropower is used as a regulator, can become rewarding. Since winds are particularly strong in the winter when energy consumption peaks and the water-reservoirs are at their lowest, a combination may, in fact, provide for a more stable energy supply than hydro-power alone (Energifakta).

However favourable, the main physical barriers are many of the same as for supplying a home market; transmission capacity, and improvements to the domestic grid are a prerequisite to an interconnection to Europe. In contrast to the innovative petroleum industry, where large corporations have provided for a continued development and renewal, Norwegian grid companies are part of a different structure. With the exemption of 4 to 5 fairly large corporations, out of a total of approximately 160 companies, a large number are SMEs, with a regional focus (Energi21). For the main part of these companies the core activities; operation and maintenance of utility and grid, have been the focal points, leaving little capacity for planning on a larger scale.

To meet the challenges of interconnection, a network in order to develop a common strategy has unified 42 of European's transmission systems operators. This initiative is part of EU' s 3rd Energy Package, and a master plan for the European electricity grid will be the first of its kind. European Network of Transmission System Operators for Electricity (ENTSO-E), which includes the Norwegian system operator, Statnett SF, will present its plan in 2010. (www.entsoe.eu).

Furthermore, The Council of European Energy Regulators (CEER) and the European Regulator's Group for Electricity and Gas (ERGEG) work for the cooperation of the energy regulators in Europe. The heads of the regulatory authorities in the EU-states constitute ERGEG, whereas CEER is a voluntary cooperation between all of the EEA countries, and, as such, including NVE as well. Both are intergovernmental, consensus-based organisations, thus, as part of EU's 3rd Energy Package a supranational organization – The European Agency for the Cooperation of Energy Regulators (ACER) – has been established. ACER prepares framework guidelines for ENTSO-E.

Direct transmission from the North Sea to the Continent, too, would require tremendous financial mobilisation. A grid sufficient to provide Europe with energy is estimated to roughly NOK 150 billion. Whether the electricity is carried onshore first, or transmitted directly, arrangements for export are needed, involving expenses connected to services, such as strategy and planning and legal preparations.

Furthermore, as a result of the development of renewables, even Northern European countries, such as the Netherlands and Germany, may experience a power-surplus in the years to come. The Netherlands, for instance, has a national target of expanding to 6 GW within 2020. Thus, potential entrepreneurs have no guarantees of a future European market.

5.6 The prospect of becoming a technology- and competence- supplier

By 2020 EU's TP Wind expects OWP to have an installed capacity of 40 GW, which represents investments in the area of NOK 800 billion, or the manufacturing, installing and operating of around 10 000 turbines. A preliminary estimate divides these investments into one third connected to the actual turbines, one fourth each to foundations and transmission. The remaining is expected to be invested in installations et cetera (Ot.prp. nr. 107 (2008-2009)). Thus, a large growth potential is connected to the various offshore-technologies, aptly illustrated by the priority given to large-scale offshore wind-parks in the United Kingdom and Germany.

The combination of high offshore competence and a considerable international initiative for offshore renewables could constitute a solid foundation for the development of successful technology clusters. Furthermore, a priority to the offshore-technologies could have positive spill-over effects on other offshore renewables, such as the immature wave, tidal and saltwater technologies, which share some of the challenges, such as mapping and regulation.

However, there are challenges connected to the diversity of this group, as well as structural issues, concerning factors such as production methods. These issues will be discussed in chapter 6. Furthermore, the present infrastructure in Norway may pose challenges to a large-scale delivery and production of OWP parts of various sizes requires cooperation between industry and the research community (LOG – Leverandørnett Olje og Gass).

6. Empirical findings and analysis

Based on the theoretical foundation and the empirical overview, this chapter will comprise an assessment of the progression of OWP in Norway. Assisted by a discussion of the main functions of a TSIS, key political issues facing the development will be analysed. Recognising the importance of the interactions between these functions, this chapter will, furthermore, identify processes of interplay between the functions, possibly leading to self-reinforcing virtuous or vicious cycles.

Different competence requirements are needed in order to become a technology supplier and to become an energy supplier (Ot.prp. nr.107 (2008-2009): 6). As discussed in the previous chapter, these development courses also, to some extent, face different barriers. Although mutually reinforcing, the success of one development course may not follow naturally from the other. The functions will therefore be analysed in relation to both the envisaged possibilities; of becoming an energy-supplier and of becoming a technology- and competence-supplier.

6.1 Analysis based on the TSIS-functions

Challenges connected to the development of Norwegian OWP will in the following by analysed by the employment of Hekkert and Negro's recent classification in the *Functions of innovation systems as a framework to understand sustainable technological change: Empirical evidence of earlier claims* (2009); entrepreneurial activities; knowledge development (learning); knowledge diffusion through networks; guidance of search; market formation; resource mobilisation and creation of legitimacy/counteract resistance to change.

6.1.1 F1: Entrepreneurial activities

Bottom-fixed wind-parks

Both medium-sized electricity producers and large corporations are initially interested in developing bottom-fixed offshore wind-parks. However, with one project licensed and none erected, up until this point, the development has not taken place in Norwegian waters. On the other side, StatoilHydro and Statkraft are engaged in projects in British waters.

Floating wind-parks

A few large corporations, of which core competence is either petroleum or electricity production, are investing human and financial capital in R&D to develop floating turbines.

One demonstration turbine is erected, operation start for two others are planned. Entrepreneurial actors are actively involved in three research institutes.

These findings certainly indicate a general entrepreneurial interest among the incumbents - in the development of both types of offshore wind-parks. The presence of large petroleum and electricity incumbents is important since these companies have the industrial capacity to engage in innovative processes, and, as such, drive the development. The interest, at this point, materializes itself in R&D, and not in transformation into commercialization. Through the considerable industrial participation in the FMEs, close interaction is ensured between the actors involved in functions 1 and 2. Knowledge diffuses through established networks, thus, capturing the essence of function 3.

Offshore technologies

There is considerable entrepreneurial activity within the technologies connected to offshore wind-parks. Initiatives are taken to form industrial clusters, with connections to the FMEs, both in Central and Western Norway. Thus, the potential embedded in Norwegian offshore competence appears to be increasingly recognised in the industrial and research communities. Furthermore, owing to the broad scope of the relevant FMEs and the active networking between the actors, the same interactions appear to be in progress here.

Function 1 is not fulfilled in order to become an ES. Yet, this proposition has to be modified since entrepreneurial actors are, in fact, actively engaged in knowledge search.

Function 1 is fulfilled in order to become a TCS. Both the primary function of entrepreneurial activity: to transform this potential into business, as well as the influence on knowledge creation are in progress.

6.1.2 F2: Knowledge development

OWP serves as a good example of how an innovation is often the result obtained through several interrelated innovations. Technologies connected to wind-power, oil and gas, electricity transmission and shipping form the foundation for further development. Since one of the largest barriers to a successful development of OWP is the level of costs, a continued knowledge development is vital, such as testing of materials that would eventually lower the investment level.

Since learning is a heterogeneous process, and knowledge emanates in a great variety of ways, a separate analysis of the four learning types outlined (Kamp 2008; Rosenberg 1982) may give a broader understanding of the knowledge development in Norwegian OWP.

Learning-by-doing and learning-by-using

Since there are presently no commercial offshore turbines in Norwegian waters, it makes little sense to analyse learning-by-doing and –using of wind-parks. However, the knowledge accumulated through construction and work experience within the land-based segment forms a foundation for further knowledge creation. As previously explained, wind-power entrepreneurs drew on the improved technology that had developed in other countries when the first Norwegian wind turbines were erected during the last half of the 1990s (Buen 2006). However, these had to be adjusted to adequately suit their conditions in rougher, often more unsheltered sitings, perhaps develop different foundation and grid technologies. Thus, during roughly 15 years of operation, incremental improvements have undoubtedly yielded a number of process and product innovations. A particular knowledge base has cumulated within the industry, parts of which can be expected to be tacit and difficult to communicate. This knowledge, initially developed from a relatively uncomplicated technology, has most of the characteristics of drawing on a synthetic knowledge base. Yet, it should be mentioned that the importance of continued development on land is somewhat contested. There are even claims that outfacing by the end of the wind parks' licence period should be considered. Within the scientific community, however, there seems to be a high degree of consensus around the fact that knowledge cumulated on land improves the foundation for further research on the offshore trajectories, and helps secure competence in all parts of the value chain.

Moreover, learning-by-using and doing has cumulated within all of the various offshore technologies connected to the petroleum industry over an even longer period of time. Having co-evolved with the build-up of oil platforms, the far older Norwegian shipping industry can be presumed to possess a complex knowledge base. It would be beyond the scope of this study to endeavour on an analysis of what type of knowledge base the heterogeneous group of offshore technologies mainly draws on. On a more general note, however, the transformation in the beginning of the Norwegian oil era of the initially foreign-controlled petroleum industry into a structure of integrated domestic companies had a large impact on the competence-level eventually achieved. This transformation was facilitated by a basic political strategy to implement not only the industry, but also the research communities, public organisations and politicians into what would become a petroleum innovation system (Engen 2009: 179). Thus, through a joint effort to enhance knowledge, this resource-based industry, initially drawing mainly on a synthetic knowledge base, evolved into becoming more science-based. This implies a combination of tacit and codified knowledge, yielding a complex knowledge base, and the prospects of high appropriability for entrepreneurial actors. Spill-over between the various companies was ensured through the political framework, which regulated the activities. To conclude, knowledge in the petroleum industry has been enhanced not only through learning-by-doing and –using, but also through learning-by-searching and –interacting.

Learning-by-searching

For complex technologies, the priority given to R&D is decisive, and a time lag between invention and commercialization is, thus, not just to be expected, but a necessity. For Norway, continued research in this field is important in order to stay in the forefront of the development. The appointment of the FMEs indicates a political willingness to achieve the desired competence level.

This impression is confirmed by the emphasis on demonstration turbines under Norwegian conditions, most notably the Hywind. However, the need for demonstration projects may be larger than what is met. At this point in the process, it is crucial to develop prototypes of single turbines, but eventually also of small wind-parks. Not only is it decisive for the technological development, but demonstration projects also give important signals to domestic as well as foreign actors. Thus, in order to stimulate interest from entrepreneurs, investors, regulatory authorities and EU-decision-makers, demonstration projects fill an important function.

All in all, however, the impression of a political will to prioritize R&D on OWP remains. The network of SFFE and the close industrial links further verify this comprehension and indicate a vibrant OWP research community. Moreover, definite goals of cost-reduction, and, thus, a focus on material competence, appear to guide the progress and further points to close industrial ties.

Hence, related to learning-by-searching; the findings under F1 - the network of actors linking F1, F2 and F3 - are confirmed. With regard to learning-by-doing and –using; the activities relevant for OWP have occurred in land-based wind-parks and in various offshore technology firms. The knowledge that has cumulated within these industries indicates a competitive advantage for Norwegian OWP. However, the knowledge transfer relies entirely on F3 to be carried out.

Function 2 is to a large extent fulfilled in order to become an ES. This is clearly indicated both by the knowledge-bases embedded in the relevant industries, but also in the priority given to research. The appointment of CEDREN, in which further research on hydro- and wind-power partnership is comprised, could further strengthen the prospect of becoming an energy-exporter.

Function 2 is most definitely fulfilled in order to become a TCS. The competence-level of the offshore technologies is based on a well-developed "absorptive capacity"; the ability to recognise the value of external knowledge, assimilate it and put it to commercial use (Cohen and Levinthal 1990). This capacity was initially ensured through petroleum policy mechanisms, high shipping-competence and the international petroleum companies who established the inward knowledge transfer in the 1970s (Engen 2009: 180). The ability to utilize this foundation for further research is, first and foremost, attended to through the FMEs.

6.1.3 F3: Knowledge diffusion through networks

Knowledge diffusion through networks occurs in learning-by-interaction; the fourth of the knowledge creation types. An extensive development of OWP relies on transfer of knowledge initially created outside of the industry. Two of the main components required for the interaction are elaborated on under the previous two functions. Furthermore, public authorities and interest organisations can greatly contribute to the facilitation of knowledge diffusion. Connections to international research communities and foreign entrepreneurs are important factors in this connection. Within Norwegian OWP, knowledge diffusion through networks is chiefly carried out through the FMEs and SFFE. As explained, the FMEs are deliberately set up to cover a broad spectrum of actors, including NVE, NORWEA and ENOVA. Conferences et cetera are also arranged and provide a setting for inward knowledge transfer. The activities involve close interaction between F2 to F3.

Function 3 is to a large extent fulfilled in order to become an ES. However, due to the complete lacking of offshore wind-parks, knowledge is not diffused through user-producer relations in connection to construction and operation of turbines.

Function 3 is also fulfilled in order to become a TCS. The establishment of technology clusters may prove to be an important area for diffusion of offshore competences. A network of heterogeneous actors cooperating and exchanging codified knowledge through the institution of the cluster could enhance the level of knowledge, but also be fed back to the research centres. Within particularly tight communities, through organizational and geographic proximity (or both) the transfer of more tacit knowledge would even be feasible. The transfer of both knowledge types, and in particular a combination of the two, could greatly enhance competitiveness.

6.1.4 F4: Guidance of search

The complex and immature OWP technology, drawing on a variety of technologies and with a variety of possible solutions, is obviously undergoing an extensive selection process. Guidance is required to ensure continued development; in order to develop the turbines, the foundations, the subsea cables et cetera into more standardized and, thus, commercial products, and, thus, to give the entire industry momentum. This means that the entire innovation process relies on sufficient guidance of search.

Feedback and expectations

Due to the fact that Norwegian OWP still has only reached pre-commercial phase, feedback as a result of diffusion lacks. However, since consumers cannot determine what kind of energy is in the grid, feedback in the form of user preferences is not likely to contribute to the guidance in a later phase either. This means that feedback connected to factors such as design and user-friendliness, which can often largely influence the selection process of a technology, are not of importance within the energy industry. Price and reliability of supply are the major concerns, thus, articulation of other requirements from the demand side cannot to a very large extent be said to emanate as a result of diffusion. Thus, since the demand side does not have a direct interest in the development of OWP, the selection process relies on political interference, such as policy targets. Climate concerns represent the exception in this respect – in the sense that end consumers may want to know the composition of the energy mix they are supplied with. This need is met through a product declaration, in which the suppliers are obliged to inform their customers of the composition of energy sources for the previous year. In addition, some of the energy suppliers offer certificates of origin, in which they guarantee the consumer that the production of renewable energy amounts to the same as the consumption (www.nve.no1).

However, while the demand side may have little incentive to prefer a particular kind of energy, wind park entrepreneurs, on the other side, have an interest in influencing the development of blades, nacelles and subsea turbine parts. Thus, the selection process that has been in progress since the 1980s is now also influenced by new offshore entrepreneurs with different needs. The selection process may further be influenced by other suppliers. The developers of repair vessels, for instance, may express their opinions on various aspects of the turbine design and by doing so, contribute to the selection process.

Expectations within the research communities can also affect technological development. Considering the recent establishment of the FMEs and the broad technological approach chosen, it seems fair to assume that the research communities positively affect the development.

Policy targets

Although the government's 3 TWh-target has undoubtedly contributed to the development of land-based wind-power, the small size of the target, as well as the fact that no new target has been set for the period after 2010, negatively affects OWP development. ENOVA has expressed a need to publicly state a target of 15 TWh within 2020, but has been met by hesitation by the government (Teknisk Ukeblad 2). Furthermore, while the 2030-target of carbon neutrality may give general climate guidance, it is difficult to consider the target as providing more specific guidance for the wind-power industry. However, climate targets of the international community, and in particular the EU Climate Package; the 20-20-20-targets, guide EU- as well as EEA-members. In fact, EU has defined offshore wind-power as its key power generating technology – a statement that further guides the international development (EWEA-report 2009). Moreover, much anticipation is connected to the impending Climate Conference in Copenhagen (COP15). To what extent the expected "Copenhagen Protocol" will serve as guidance for OWP remains to be seen.

Laws, regulations and plans

The EU directive

The 20-20-20-targets are legally binding through the EU directive. However, since the consequences of the directive are not clear for Norway at this point, it remains to be seen whether the government will use the demands as a lever to enforce a higher share of renewables in the energy mix. If the negotiations with the EU result in exemptions for Norway due to the hydropower production, then, obviously, the directive will be of less value to the wind-power industry. The hesitation to set a new national wind-power target should be seen in connection to the EU-negotiations. Thus, the performance of Norwegian OWP largely depends on the outcome of these adjustments.

The Electricity Act (EL) and havenergilova

The national legal framework can greatly influence technological development. The EL of 1991, for instance, brought privatization of the power companies, which led to a fall in electricity prices for most regions, and eventually brought wind-power development to a halt. Thus, an activity within F4 was negatively linked to F5; market formation. The EL regulates sheltered waters. Up until havenergilova is passed, presumably in 2012, waters outside of the baseline remain uncovered by law. This means that no activity is likely to take place in these waters until then, and that the final formulation and jurisdiction is yet unknown.

Much anticipation is connected to havenergilova, and it does indicate a political will to build wind-parks outside of the base line. The parallels to the licensing of the petroleum sector, in particular, point in this direction as it gives clear signals to the entrepreneurial actors. The impact assessments and the mapping connected to infrastructure and market would also give guidance to entrepreneurs and facilitate the licensing process. Thus, havenergilova, and the mapping connected to it, could establish close links between F4 and F1. Furthermore, the impact assessment, considering shipping, defence, disturbance of seabed, marine life and so forth would enhance legitimacy, thus linking F4 to F7. In order to avoid being caught between conflicting interests, this mapping is of great importance to the future of the offshore renewables.

An Energy Master Plan

An Energy Master Plan appears to be lacking from the administrative system in Norway. A master plan provides sustainability and predictability for the entire energy sector of a country.

Thus, a comprehensive plan, where OWP is implemented as a contributor to the total energy mix, would give guidance as well as legitimacy. Furthermore, being on a superior level, a master plan could also enable industrial growth, in particular new energy intensive industries. Considering the technical potential of OWP, a plan of this extent could implement, for instance, the facilitation of easy accessible power-supply, following the traditional industrial pattern of Norwegian hydropower. In order to strengthen coordination, a council was established in 2007 – Energirådet; comprising actors from a wide variety of organizations; research, industry and public authorities (MPE (3)). However, the council's optimistic report on OWP does not match the actual measures taken up until this point (MPE (4)).

A Wind-power Master Plan

For entirely different reasons, some actors state the need for a more specific Wind-power master plan. On one hand, it is being argued that a master plan will help speed up the licensing process and provide proper guidelines. On the other hand, opponents to wind-power may have even more to gain from a master plan, as it could help to rule out potential projects. However, drawing up a master plan for the exploitation of wind, may well be an impossible mission as wind cannot be compared to the more constant hydropower. Furthermore, havenergilova could render a master plan irrelevant, at least for offshore production.

Summing up these diverse guiding activities gives a somewhat inconclusive answer. Feedback does not provide much guidance, a fact that puts more pressure on the formulation of policy targets. However, as of next year, no definite targets for wind-power production have been set. Plans, on various levels, appear to be absent too. The main exemption being havenergilova, due in two to three years, of which the outcome is yet unknown. The only fairly certain positive guidance emerges from the research community.

Function 4 is, at this point, to a very small extent fulfilled in order to become an ES.

Function 4 is also to a very small extent fulfilled in order to become a TCS. However, the situation for the various offshore technologies is different – in the sense that some of the products are commercialized, and the companies may receive feedback, for instance from foreign actors.

6.1.5 F5: Market formation

Market formation related to the development of an ES industry

The measures taken to form a market space are vital to the survival of an immature technology. Inconsistent policy measures of the last 30 years have signalled unpredictability, resulting in generally low diffusion of wind-power in Norway. There is reason to assume that the unpredictability has negatively influenced potential offshore entrepreneurs. Nevertheless, the investment subsidy scheme, and even more importantly, resumption of the certificates negotiation with Sweden, has given incentives to 12 bottom-fixed offshore wind-park projects, presently notified to NVE. The recent agreement on a certificates system, due to start in 2012, is expected to increase the number of license applicants. However, in the case of this particular agreement, it has only just been signed and there is uncertainty connected to the actual content. According to one of the larger power producers, the price of the present Swedish certificates would not have resulted in new large wind-parks had they been introduced today (Teknisk Ukeblad 3).

Furthermore, while mature land-based wind-power may be best served by a niche market system, the offshore turbines are still considered immature. Keeping in mind that a certificates scheme exposes the technology to the competition from other renewables, neither of the offshore trajectories can rely on this measure, which appears mostly to be suitable for bio-energy and small-scale hydropower, in addition to land-based wind-parks. In this context it is, once again, necessary to separate between floating and bottom-fixed solutions. The bottom-fixed turbines, although starting to become internationally commercialised, lack several of the features associated with a mature technology, particularly connected to the level of costs, and is still undergoing R&D. Thus, for this particular technology, there is a fair reason to question the suitability of the green certificates. Indeed, the recently licensed Havsul I is not likely to be built solely on the economic basis of the certificates scheme – the chairman claiming the need for additional policy tools (www.norwea.no). Thus, while the most conspicuous impediment to the bottom-fixed projects is the lack of licence, which again is linked to the reading of havenergilova, the wind-parks might not have been built even if the licenses had been granted at this point. Hence, a more particular regime for the commercialisation of offshore turbines appears to be necessary. For the time being, floating turbines, on the other hand, appear to be handled with the appropriate tool: extensive R&D.

Whatever the content of the certificates agreement may be, and even if other policy measures are planned to complement it, the most severe barrier for the diffusion of Norwegian OWP is still the prospect of power-surplus. Thus, entrance into the largely satisfied Norwegian energy market cannot be solved by increasing the financial support. A power-surplus would inevitably reduce the power price, which again would slow investments in renewables projects – much like the chain of events occurring after the privatisation in 1991. Moreover, since the owners of the majority of the Norwegian power companies are municipalities and counties, this development could have serious social and economic consequences. This means that the discourse over policy measures for renewables could soon become less relevant.

A discourse over market formation for OWP is perhaps better served if related to *other* markets and, thus, domestic transmission capacity and interconnection to Europe – the two obviously interdependent and demanding on resource mobilisation (6.1.6), long-term strategies and international cooperation. Incidentally, specific plans for improvement of domestic grid is also implemented in EU's NREAP form, and, as such, part of the ongoing directive-negotiations.

Development of the domestic grid, with a view for interconnection, however, meets the structural challenges of the grid sector. Due to the restricted capacity and level of ambition of the many SMEs, research-based innovation has been practised to a limited extent and grid improvements have been on a regional level. Nevertheless, the larger companies, in particular Statnett, do engage in innovation projects, sometimes in cooperation with NVE. Generally speaking, however, the structure of a large number of SMEs cannot be said to have contributed to a focus on international markets. The potentially highly rewarding hydro and wind collaboration can be assumed to further challenge long-term planning and resource mobilisation within this sector.

With regard to international cooperation, several initiatives have been taken through EU's 3rd energy package, such as the formation of a new supranational EU-organization, ACER, in order to enhance decision-making and efficiency. The establishment of ACER, for the cooperation of the energy regulators and the preparation of guidelines for the transmission system operators, indicate a will on European level to improve interconnection. Furthermore, NVE and Statnett participate in their respective organizations, attending to Norwegian interests. The FMEs, too, are internationally connected and have, moreover, implemented grid connection into their research. Thus, several institutions provide interaction between other European and various Norwegian actors; researchers as well as entrepreneurs and public authorities. The interest in interconnection is confirmed by The European Wind Energy Association (EWEA), which, in its new report, proposes several new interconnectors linking Norway to the Continent.

Yet, while OWP may depend on interconnection to the Continent to become an ES, this process is mutually reinforcing. If Norwegian OWP does not appear to develop into commercialisation, there is a risk of being excluded from the development as the European grid is being extended and reinforced. A European grid development without adequate interconnection to Norway could have severe consequences for the industry.

Furthermore, since the vigorous growth of renewable energy in some EU-countries could potentially lead to a satisfied energy-market even in Northern Europe, there is reason to maintain a tight connection to the EU and to establish long-term planning. If markets are neither to be found in the Nordic countries nor in Northern Europe, Norway's geographical position may simply be the largest barrier - considering the costs of developing sufficient grid capacity across the North Sea alone is estimated to NOK 150 billion.

The barriers connected to transmission and lack of possible energy markets, point to a mismatch between the policy measures taken to develop the technologies, particularly within F2, F3 and the measures taken to develop and arrange for a demand; F5. This mismatch indicates fragmented policy making and a need to raise the policy measures to a higher, more supervisory level in order to take all aspects into consideration. The recognition of the need of an overall plan indicates a close link between F4 and F5, and, thus, points back to lack of an energy plan. An overall, long-term plan could facilitate the electrification of oil and gas platforms and, even more importantly, the previously mentioned establishment of new power intensive-industry; and, as such, provide new markets.

Countries like Germany, Denmark and United Kingdom have integrated all aspects into an overall plan, encompassing industry concerns as well as research and other policy areas. These markets are considered to be the most promising for OWP (EWEA-report 2009). Germany, in particular, has a strong connection between energy and industry policy. Although this tight interplay may work against the goal of establishing a common support regime, such as international green certificates, it undoubtedly enhances the prospects of German industry.

Market formation related to the development of a TCS industry

Whether or not a large-scale development of offshore wind-parks will take place in Norwegian waters, the international development continues. The large potential for Norwegian offshore-technologies is confirmed by EWEA's report; "The predominant offshore market is planned for the North and Baltic Seas in the short to medium terms. Countries in this area can expect to reap the benefits of offshore wind development". Thus, whereas ES is likely to experience limited markets in the geographic proximity, TCS can look forward to growing markets. Furthermore, the physical impediments connected to transmission do not constrain the supply of technology and competence. These are promising factors which indicate the possibility to co-evolve with offshore wind-parks as they mature.

However, considering the integrated plans of some of the other countries bordering on the North Sea, competition can be expected to become fierce. Due to factors such as proximity and infrastructure, as well as potential agreements embedded in the contracts, entrepreneurs could be expected to prefer local TCS. From this follows that the large volume productions planned in British waters, in which investment and installation is largely carried out by Norwegian actors, will not automatically be supplied by Norwegian technology and competence. Thus, a focus on enhanced competitiveness, and, thus, appropriate policy measures, is vital. Although interlinked, it is reasonable to assume that the industrial actors within this very diverse group have different requirements in order to become competitive. To avoid bottlenecks, all links in the value chain need to be evaluated separately, and receive support according to individual requirements and the specific markets they operate in. This understanding, once again, points back to the need to analyse this industry from an aggregate level and, thus, to develop an overall coordinating plan; F4.

The findings in functions 4 and 5 indicate a need for an integrated overall plan with a clear industrial perspective. Having different objectives, the traditional separation between an industrial policy and an energy policy does not provide for sufficient coordination. Whereas the industrial policy's main objectives relate to industrial growth and increased competitiveness, the energy policy is concerned with energy-related questions, such as how, where and what kind of energy to prioritize.

Function 5 is not fulfilled in order to become an ES; a market has not been created for offshore wind-parks. Appropriate policy measures have not been introduced, and there appears to be a lack of actual energy markets.

Function 5 appears to be largely fulfilled in order to become a TCS. The market for these products is growing. However, in order secure competitiveness and provide appropriate tools, there is a need for an evaluation of this heterogeneous group, involving coordination between industrial and energy concerns.

6.1.6 F6: Resource mobilisation

Mobilisation of resources is decisive for the performance of a technology, and closely linked to several of the other functions. Entrepreneurial activity (F1), knowledge creation (F2) and market formation (F5) rely on the mobilisation of human and financial mobilisation.

As discussed, major, affluent corporations are involved in the development of OWP, within R&D as well as commercialising abroad. Within the segment of bottom-fixed wind-parks, power companies are taking an interest. Many of these companies have reached considerable sizes since the privatization. Furthermore, several have merged or engaged in other wind-power collaborations. Thus, there are actors with considerable financial means, as well as human capital, within the OWP industry. The participation of these actors is of major importance, and point to mutually reinforcing interactions between F6 and functions 1 and 2.

Thus, in comparison to the many SMEs within the monopolistic grid developing segment, several power companies with an obvious interest in transmission improvements, have the means to contribute to a grid development. Again, this situation of large power companies and small grid companies point to the need for coordination – this time of resources, and, thus to the need for closer links between F6 and F4.

Hence, the poor functioning of functions 4 and 5 appear to negatively affect the functioning of F6. This is clearly indicated by the lack of foreign investments in Norwegian renewable energy. International petroleum corporations yearly invest around NOK 145 billion in Norwegian oil and gas. By comparison, the investments made in Norwegian renewable energy are practically non-existent, amounting to NOK 4 billion in governmental investments

(Dagbladet 1). These numbers, and the poor functioning of F4 and F5, can be related back to the fact that the government has an interest in continued oil exploration to finance the state budget. This is further indicated by the ownership-structure of StatoilHydro, being currently 67 % state-owned. This means that the same department that draws up the authorization for ENOVA has, in fact, vested interests in the production of fossil fuels (Dagbladet 2). Thus, conflicting interests within MPE appear to impede the OWP development.

This brings us to resource mobilisation through the state budget. According to the draft law, this year allocations for RENERGI is increased with 60% (Ot.prp. nr. 107 (2008-2009)). This increase corresponds to my previous findings of relatively well-functioning R&D activities. However, the EU's climate package opens up for a temporary exemption from the state aid regulations. Thus, there is still reason to question the financial support, and whether this opportunity is fully taken advantage of, even in connection to R&D. It seems perhaps particularly relevant to relate this question back to the demonstration projects. Although ENOVA's new demonstration programme may ensure progress, this programme exposes testing of offshore turbines to the competition of testing of other ENOVA-activities, such as energy-efficiency (Ot.prp. nr.107 (2008-2009)). The matter of the state aid regulations also relates back to the measures taken to create a market space, pointing to a negative influence from F6 to F5.

Function 6 is only partly fulfilled in order to become an ES. Resources are, or can be, mobilized within the industrial segment. However, this is negatively linked to the lack of public resource mobilisation towards market formation. Resource mobilisation for the purpose of R&D appears to be relatively well taken care of.

Function 6 is also partly fulfilled in order to become a TCS. Since this development path is less dependent on the formation of market space, this function may be fulfilled to a higher extent for the prospect of becoming a TCS.

6.1.7 F7: Creating legitimacy/counteract resistance to change

While creating legitimacy has proved to be a challenging function to fulfil for the developers of land-based wind-power, there is reason to anticipate less controversy over the offshore trajectories. Local opposition, often based on issues connected to noise or visibility, such as reflection or shading, is likely to decrease considerably due to the relocation of the turbines.

This means that the previously strong alliances of local resistance and nature conservation organisations collapse, leaving the latter to fight the battles over seabirds and breeding grounds. This process has led to a general interpretation of the wind-power industry in Norway as having been “driven to sea”.

However, resistance to wind-power may still arise over bottom-fixed wind-parks. The turbines currently in operation are normally situated less than 10 kilometres off the shores, thus similar issues over disturbance and the same kind of alliances that emerged over land-based projects may be encountered. Furthermore, entrepreneurs could face resistance both from other industrial sectors, such as shipping and fishing, and from public actors, such as defence organisations.

Much anticipation is connected to the proposed havenergilova (Ot.prp. nr.107 (2008-2009)), as well as the NVE-project connected to it. This broadly composed group’s mapping of the waters outside of the baseline is expected to secure the interests of a considerable part of the actors involved in future OWP-projects. Thorough impact assessments will contribute to the avoidance of controversies with nature conservationists, as well as other industries and public actors. Since there is insecurity connected to the final jurisdiction of havenergilova, this leaves the shallow waters somewhat in a grey area for the time being. However, since none of the notified offshore wind-parks (some planned inside and some outside of the baseline) will be granted licence before the law comes into force (except for Havsul I), there is reason to assume that the law will have influence over the shallow waters area as well. Moreover, this area is currently also protected through MD, which gives approval in addition to MPE/NVE. All in all, these interaction point to tight, at least future connections between F7 and F4, guidance of search.

Thus, the task of creating legitimacy does not appear as challenging as many of the other TSIS-functions. Many of the opponents to land-based wind-power have no strong objections to OWP; some are even in favour of this development. Yet, it should be noted that – at this point in time – it is far too early to make categorical statements about the public opinion on OWP. However, most NGOs strongly favour OWP as a means to reduce CO2 emissions. Thus, environmental organisations in general as well as NORWEA serve as advocates and work towards influencing the political agenda.

Function 7 is largely fulfilled in order to become an ES. A reservation should be made with the regard to havenergilova, as the content remains to be seen.

Function 7 is not to the same extent relevant for TCS, since creating legitimacy mostly relates to the wind turbines. However, being interlinked, the creation of legitimacy for wind-parks benefits the offshore-technologies as well. As for the possible resistance to particular products or production sites, this subject has not been looked into during this study.

6.2 Summing up the performance of the TSIS-functions

When analysed with the assistance of Hekkert and Negro's TSIS-functions, the performance of a future Norwegian OWP innovation system appears promising only to a limited extent. Except for the lack of entrepreneurial activities in connection to the erection of wind-parks, the 3 first functions are to a high extent fulfilled for both development paths. The 3 following functions give more reason for concern. Thus, in general, it appears that the policy instruments stimulate technological development; *technology push*, but is not stimulating the demand for the technology; *demand pull*. Table 2 shows a rough overview of the findings, analysed along the two selected dimensions; the prospect of becoming an energy supplier (ES) and the prospect of becoming a technology- and competence-supplier (TCS). With the very significant exception of function 4; guidance of search, a majority of the functions appear to be fulfilled in order to become a TCS. The findings indicate a less promising future for the prospect of becoming an ES. Large barriers, particularly in connection to functions 4 and 5 impede commercialization of offshore wind-parks.

As it deprives the industry of momentum, the lack of guidance negatively affects all the other functions, in particular 1, 5, 6 and even 7. Thus, despite early days, one might see the contour of a vicious cycle, in which a negative development of F4 is followed by a negative performance in F5, leading ultimately to poor functioning of F6 and F1.

6.2.1 Mutually reinforcing developments

Although the two development paths have been analysed separately, it is important to recognise the fact they mutually influence each other. Even if technology and competence suppliers appear to have promising global markets, there is a need for working wind-parks in Norwegian waters. The development of other resource-based Norwegian industries has proven the importance of learning-by-using and –doing. Prototypes alone do not provide a solid foundation for the continued development of knowledge, and there is need to cumulate more tacit forms of knowledge from working offshore turbines as well. Thus, when the framework conditions for turning OWP into an ES industry are poor, this negatively affects the prospects of becoming a TCS. The success of the hydro and petroleum developments came through the exploitation of the resources.

The development of wind-parks, on the other side, depends on a dynamic TCS industry. Offshore wind-turbines need technologies and competence adapted for Norwegian offshore conditions as well as local supply to keep costs down.

TSIS' 7 functions ↓	A future Norwegian offshore wind-power innovation system →	Fulfilment in order to become an energy supplier (ES)	Fulfilment in order to become a technology- and competence supplier (TCS)
Entrepreneurial activities;	F1	Not fulfilled. But actively engaged in R&D	Fulfilled
Knowledge development (learning);	F2	Largely fulfilled	Fulfilled
Knowledge diffusion through networks;	F3	Largely fulfilled	Fulfilled
Guidance of search;	F4	To a very small degree fulfilled	To a very small degree fulfilled
Market formation;	F5	Not fulfilled	Largely fulfilled
Resource mobilisation;	F6	Partly fulfilled (-)	Partly fulfilled (+)
Creation of legitimacy/ counteract resistance to change;	F7	Largely fulfilled	Largely fulfilled. But not to same extent relevant

Table 2

6.3 Structural advantages and disadvantages

As discussed, Norwegian industrial history has during the 20th century been characterized by a structure of large-scale companies, possessing the resources to influence technological development (Wicken 2007). This path-dependent process, developed through the exploitation of hydropower, and reinforced during the oil era, has enabled the development of an initially resource-based economy from drawing on synthetic knowledge towards a more complex knowledge base, drawing on a combination of synthetic and analytic knowledge. The strong path-dependency, sometimes referred to as “The Norwegian Paradox”, is described by Fagerberg et al. (forthcoming) in the following way; “Norway’s resource-based sectors have displayed considerable dynamism in developing knowledge and adapting to new challenges". This dynamic development indicates strong links between the actors within F1, F2 and F3. Furthermore, the pattern points to a deliberate political intervention, and, thus, strong systemic links between industrial, scientific and public actors, linking the three functions closely to F4 and F5.

The Norwegian path-dependency influences the selection environment. Whereas new entrants with few common features with the strong existing sectors may find the environment poorly adapted to their needs (Fagerberg et al. (forthcoming)), the same pattern should be expected to provide support for entrants emanating from the exact two industries which formed its basis. It seems that the reason why a similar development has not yet become clearly apparent within this TCS industry is connected to the poor functioning of F4 and F5. This understanding points to one of the main difference between the successful development of hydropower and petroleum and the issue at hand; the lack of a politically integrated system. The other main difference has already been pointed out: the lack of mutually reinforcing dynamics between ES and TCS, due to the fact no energy production is going on within OWP.

There are also particular structural issues within the petroleum sector that need to be addressed. Technology and competence activities within the petroleum sector are accustomed to high profitability. Adjusting to an industry where earnings may be expected to be lower may pose a challenges related to cost-efficiency. This difference in level of costs, puts pressure on the research community (F2), and can, moreover, negatively affect resource mobilisation (F6).

Furthermore, the petroleum development brought structural inertias to the production pattern. Since every project was different, the industry became locked-in to a pattern of single productions. This feature separates the petroleum subcontractors from the OWP technologies. Wind parks, to a much larger extent, involve automation and serial production. This legacy from the petroleum industry, further highlight the importance of raising the coordination to a higher level, comprising industry as well as energy issues.

7. Concluding remarks

Inspired by a functions approach to TSIS, this paper has discussed key political issues connected to the development of OWP in Norway. The possibility of a future innovation system has been discussed along two dimensions, identified to be the possible development paths for OWP; the prospect of becoming an energy supplier, and the prospect of becoming a technology- and competence supplier.

7.1 The performance of the functions

Generally, the development of Norwegian OWP is characterized by a high degree of *technology push*, combined with a lack of *demand pull*. Despite the lack of actual energy production from OWP, and, thus, lack of learning-by-doing and –using, there is ample room for learning-by-searching and -interaction in what appears to be vibrant research communities. However, the lack of guidance severely affects several of the other functions. An insufficient functioning of market formation is clear, and negative links between the two latter is constantly recurring. This negative interaction influences entrepreneurial activities and resource mobilisation, and does not increase legitimacy (although public opinion generally is positive). Within a majority of the functions, the discussions lead to similar conclusions; the need for a coordinated plan, comprising all aspects of the development. Although havenergilova is anticipated to give considerable guidance and positively affect the selection process, the need for the OWP-development to be analysed on an aggregate level, taking industrial as well energy concerns into consideration is clear.

7.2 Energy-supply, technology-and competence-supply, or both?

The beginning of a vicious cycle does not leave good prospects for becoming an ES. Keeping in mind the strong competitiveness and time aspect, the prospect of becoming a TCS is considerably higher, in particular due to growing markets. However, there are two factors which separate the OWP-development from the previously successful hydropower and petroleum developments. Firstly, it is important to recognise the fact that ES and TCS mutually reinforce each other. For the purpose of further knowledge-development, TCS needs a certain amount working wind-parks, and not just prototypes. Secondly, the lack of a politically integrated system appears from the analysis. Political intervention characterized the development of hydropower and petroleum, contributing to the high competence level. A deliberate and high priority to TCS is recommended, but not without the company of wind-parks.

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